EXAMINING THE USER EXPERIENCE IN CLIMATE-ADAPTIVE POLICIES: TUCSON ARIZONA’S RESIDENTIAL GRAY WATER RECYCLING

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By

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ABSTRACT

Urban areas face various resource strains in adapting to climate change. Adaptive management strategies can provide ways for cities to transition to more resilient policies, however, adaptive management requires that governments be willing to be reflexive, taking in feedback for iteration, as they design policies to address complex social-ecological challenges. Acknowledging the fundamental role that stakeholders and 'end users' play in implementing said policies is imperative to achieving the desired policy outcomes.

This research explores Tucson Arizona's Residential Graywater Ordinance (RGWO) (a building ordinance intended to reduce potable water use) as a case study example of a climate-adaptive policy. The effectiveness of the RGWO was evaluated through nine in-depth stakeholder interviews and the surveying 57 home owners (end users) about their experience reusing water from their homes. Only six of the participants currently (4) or previously (2) (estimated 10.5%) of surveyed residents have reused graywater from their homes. The results indicate that the ordinance did not facilitate additional water reuse at the residential scale due to various barriers experienced by end users. Tying together user experience research, socio-ecological system thinking, climate-adaptive policy design, and environmental psychology, this research examines the role of user experience in climate-adaptive policy design while offering a research framework for synthesizing new fields.

BIOGRAPHICAL SKETCH

An affinity for over analyzing social systems and a love for both design and the natural world led me to the Sustainable Design Studies focus in Human-Environment Relations. Originally from the Appalachian Mountains of South-western Virginia, I graduated from the University of Virginia with a BA in Cultural Anthropology and a minor in Urban and Environmental Planning in 2012. A few years later, I stumbled into a book store and discovered a book called “Human Ecology”. Suddenly I had been given the vocabulary I was missing to connect design, sustainable living practices, systems thinking and social science. I applied to Cornell University a few months later and joined the Department of Design and Environmental Analysis the following year. Ever since, I have wanted to use user experience / design research and creative problem solving to help develop more viable and sustainable systems through behavior change. I hope this thesis is the first step of many in doing so.

ACKNOWLEDGEMENTS

Just as a person cannot be a person without other people, a Masters thesis cannot be a thesis without the support, belief and guidance of a great number of individuals. I would not have completed this work without the support and encouragement from my immediate family (especially my parents, Beth and Andy Bell) and friends. Nor would it be possible without the patient and helpful feedback and guidance from my advisor and chair, Dr. Nancy Wells, who endured my many muddled ideas as I climbed Research Mountain and who has given myself and others a better understanding of what it means to have a foundational and supportive academic mentor. I also thank Joshua Cerra, my minor member, whose sincere enthusiasm for linking human behavior to positive change in the built and natural environment have been infectious for many of his students, myself included. I am also grateful to the many instructors (and colleagues) who encouraged my intellectual growth and curiosity during my time at Cornell, especially Sheila Danko whose ability to believe in other people's creative potential is wonderfully contagious. Thanks as well to the group of friends and colleagues I call family, whose support was, and continues to be, invaluable.

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LIST OF DEFFINITIONS AND ABBREVIATIONS

Adaptive Law (Arnold, 2008).
Laws or policies created to be responsive to rapid, unexpected change, characterized by distributed governance authority, multi-level civic engagement and resource management by including stakeholders at multiple scales of a management endeavor.

Adaptive Management (Swanson et. al, 2009; Pahl-wostl, 2007).

A management process that responds to rapid, unexpected change by incorporating project feedback and adaptation into the management design.

Climate-Adaptive Policies (CAPs) (Avari et al., 2006).
Policies that operate within the umbrella of adaptive management and adaptive law but designed to achieve a specific goal or outcome related to resource management and climate change. CAP's can act as "pathways" to create more climate resilient cities.

Graywater (Domnech & Sauri, 2010).
Wastewater originating from residential clothes washers, bathtubs, showers, and sinks but does not include wastewater from kitchen sinks, dishwashers and toilets.

Social-ecological resilience (Chapin et al. 2010, Biggs et al. 2015).
The ability to adapt or transform social-ecological systems in the face of change in ways that continue to support human needs.

User Experience Research (Nunnally & Farkas, 2016).
User experience research is the investigation of users (of products, places, services etc.) and their needs or requirements in a given 'user' context. The point of user experience research is to add context and insight into the process of designing the user experience. A variety of techniques, tools, and methodologies can be used to reach conclusions, determine facts, and uncover problems related to the user experience being studied.

Residential Gray Water Ordinance (RGWO) (City of Tucson, 2010).
Tucson Arizona's 2010 Residential Gray Water Ordinance (RGWO) requires that new single family and duplex housing be built with separate graywater plumbing to enable wastewater recycling for irrigation. Intended as a policy intervention to better utilize residential potable water resources in Arizona, the RGWO is an effort to more effectively use water resources in a desert environment while reducing potable water demand for outdoor water use.

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Using Tucson Arizona's Residential Gray Water Ordinance (RGWO) as a case study example, this research evaluates the role stakeholders can play in the success or failure of a policy intended to help a city transition to climate-adaptive practices through the conservation of potable water. This thesis evaluates whether or not the policy was effective in engaging the 'end user' (homeowners) and presents a framework for identifying collective barriers that stakeholders face in designing and using graywater systems at the residential scale. By considering the RGWO as an example of a Climate-adaptive Policy (CAP), a local policy intended to create a specific adaptive response to water shortage (i.e. water reuse), this research explores the importance of the user-experience in creating successful CAPs.

The Residential Gray Water Ordinance. Tucson Arizona's 2010 Residential Gray Water Ordinance (RGWO) requires that new single family and duplex housing be built with separate graywater plumbing to enable wastewater recycling for irrigation. The RGWO is an effort to more effectively use water resources in a desert environment while reducing potable water demand for outdoor water use.

In Arizona, potable water demand is projected to increase from about 104,000 acre-feet in 2012 (actual) to between 120,000 and 145,000 acre-feet per year by 2030. By 2050, the potable demand will likely range from 147,000 to 178,000 acre-feet per year (City of Tucson Water, 2012). Using potable water for outdoor use is still very common, and accounts for a high percentage of residential water use. In Tucson, where low water use landscaping is more common, outdoor watering still accounts for about 40 percent of residential water use (Eden, Gelt, & Pitzer, 2007). According to Chuck Graf from the Arizona Department of Environmental Quality:

> Tucson's data indicate that graywater could account for 27 percent of total water usage. For a family of four, more than 100 gallons of potential gray water is generated per day. If this volume is substituted for part of the water used outdoors, household potable water usage would drop by 21 gallons per capita per day—a significant savings. Tucson also compiled data for multi-family residential use. These data indicate that about 30 percent of the supplied water is available for use as graywater *if appropriate plumbing is in place* (2012, p. 1).

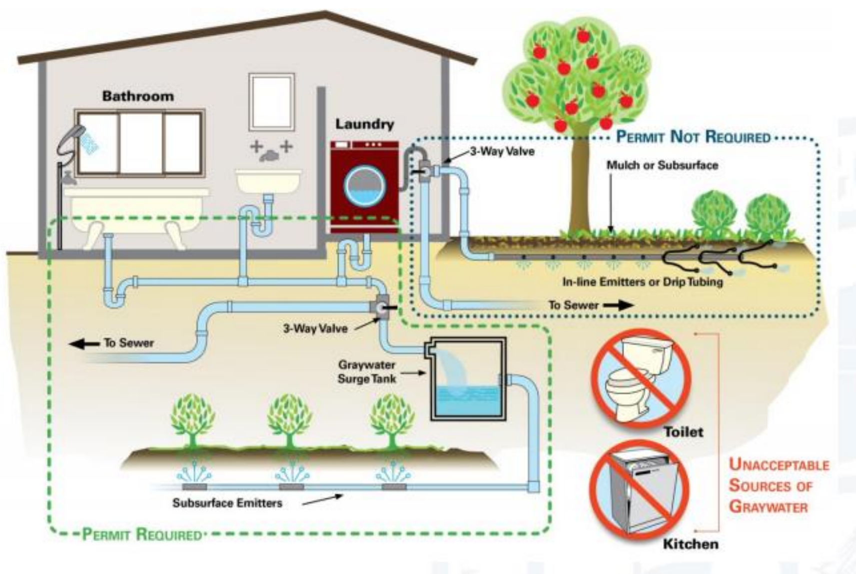

Figure 1. Sample home graywater system (disregard permit markings).

From City of San Diego Public Utilities Department

Problem Statement. If cities are to adapt to the changing climate and resource scarcity due to increasing urbanization, they must reimagine how water is used and distributed in urban areas, and how policies can enable collective water conservation. In water-scarce regions, graywater (water from showers, sinks and laundry) could be reused to diversify the water supply portfolio, reduce potable water demand and provide greater resiliency in the face of uncertain water availability.

The City of Tucson stated that:

> Gray water is a valuable resource as it makes 'double use' of potable water that would otherwise go down the drain. ...Gray water can save typical household 13,000 gallons of potable water per year…[and] a desert community should do everything possible to conserve water and promote efficient use of water resources (Canfield, 2010, p. 9).

However, the implementation of local and regional policies often depends on a variety of unforeseen social factors. Although more than 2,000 homes have been built since passage of the ordinance, there is no existing information available indicating whether the ordinance has indeed facilitated graywater reuse, and what factors the policy's end users (the homeowners) face in reducing potable water use by installing and maintaining graywater systems.

This research approaches the RGWO as an example of a regional CAP designed to help the city of Tucson transition to more sustainable water use patterns. It considers the fit between behavior and environmental context in Tucson's Residential Gray Water Ordinance, and how such fit influences the ultimate success of the policy. The results of this research may shed light on how and why other CAPs may be designed to integrate behavioral feedback from end users to ultimately improve policy implementation.

Research Studies. The research was conducted as two studies:

1. *Study 1: Stakeholder Insight.* This study considers the role of stakeholders in enacting the Residential Graywater Ordinance (RGWO) and was used to inform Study 2, the quantitative survey portion, of this research. An ecological model of behavior (exploring individual, interpersonal, organizational, community and policy levels) was used as a framework for analyzing the complex relationship between climate-adaptive policy initiatives and their success or failure on the individual level (Bronfenbrenner & Morris, 2007, Bronfenbrenner & Evans, 2000, McLeroy et al., 1988).

2. *Study 2: Policy Impact Evaluation.* Data from the in-depth guided interviews were used to inform the creation a quantitative survey to evaluate whether the RGWO had been successful in facilitating water reuse (and potable water savings).

Together, the two studies provide insight into how different stakeholders can impact policy implementation while providing suggestions for other cities hoping to institute similar policies.

Importance.

Theoretical. Cities hoping to transition towards more sustainable (resilient) policies around resource management will have to embrace a system thinking approach to problem solving, including iterative approaches to solving complex problems. Many cities are Considering the role of the end user in policy creation and implementation may become increasingly important as cities try to become more agile and responsive to climate change induced challenges. Climate-adaptive Policies (CAPs) can act as "pathway" policies to help cities test out solutions to novel problems.

Case Study Specific. In upcoming years, water cycles will be significantly impacted by global climate change, and demand for potable water will increase due to growing urban populations (Sokolow et al., 2016). With the majority of the world population now living in cities (Daffara, 2011), urban areas have become the primary consumers of resources (Alberti et. al., 2003), forcing many to deal with resource constraints by developing adaptive strategies to rethink city infrastructure in relation to natural resources.

Various researchers have suggested that reusing water may be a strategy for better utilizing water resources (Ángel, Zavala,Vega, Andrea, & Miranda, 2016; Leas, Dare, Al-delaimy, & Mena, 2014; Marks, & Zadoroznyj, 2017). Graywater[1] in the U.S. is defined as wastewater from residential clothes washers, bathtubs, showers, and sinks not including wastewater from kitchen sinks, dishwashers or toilets (Roesner et al., 2006), and accounts for approximately 45% of household water (DeOreo et al., 2016).

In the arid Southwest, 60 to 70% of municipal water use occurs at a residential scale, with most water being used outdoors for landscaping and pools (Holway 2009), and as mentioned earlier, even in water-conscious cities like Tucson, outdoor water use can represent 40 percent of residential water use (Eden, Gelt, & Pitzer, 2007). Water cycle fluctuation will be significantly impacted by global climate change in upcoming decades and additional demand for potable water will increase due to growing urban populations (Sokolow et al., 2016). The current water use patterns mentioned above, combined with the expected increases in both urban living and water demand, may create a resource strain for urban areas. For cities to adapt to climate change, policy makers must imagine how water policy can enable widespread long-term conservation (Urwin, K., & Jordan, A., 2008).

The reuse of residential waste water (graywater) for shading/irrigation is one underutilized option for reducing potable water use, municipal energy use, and greenhouse gas emissions, with seemingly little negative impact on public health; it is also has the potential to expand water supplies by reducing municipal water demand and decreasing water transportation and treatment energy use (Sokolow 2016, EPA, 2012, Yu, Z., Rahardianto, DeShazo, Stenstrom, & Cohen, 2013). However, more research is needed on potential impacts on human health and long term impacts of graywater on plants, soil chemistry and microbiology (Roesner, et al,

[1] The spelling "graywater" will be used in this research unless quoted from another source, as spellings of "gray water", "greywater", and "grey water" are also used with frequency.

2006)[2]. Graywater reuse requires both policy support and the behavioral input of citizens for widespread success, therefore it is critical to consider stakeholder needs at various stages of policy implementation.

Literature Review

Given the inherently interdisciplinary nature of the topic of CAPs and the Residential Gray Water Ordinance (RGWO) in particular, this literature review spans several topics: 1) The role of climate-adaptive policies (CAPs) in addressing climate change issues 2) a discussion of an environmental psychology framework, the Ecological Model, for analyzing user-experience in CAPs, 3) a discussion of graywater and sustainable water management, 4) an overview of the RGWO, and 5) a brief history of graywater in the US and Arizona.

Climate-Adaptive Policies: Transitioning with Climate Change

If climate change is the driver and resilience the goal, then adaptation is the process through which transition will occur. In this sense, climate experiments are where governance is located; they represent the practical dimension of adaptation – what happens in practice, 'on the ground', when policymakers, researchers, businesses and communities are charged with finding new paths (Evans, 2011, p. 225)

CAPs are policies that operate within the umbrella of adaptive management and adaptive law (see definition pg. 11) but designed to achieve a specific goal or outcome related to resource management and climate change. CAP's can act as "pathway" policies to create more climate resilient cities. Although not explicitly termed a "Climate-Adaptive Policy" by the City of Tucson, the Residential Gray Water Ordinance of Tucson, Arizona is one example of a policy addressing how the built environment interacts with water resources and human behaviors and to

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[2] Numerous studies have been devoted to identifying the environmental impacts of graywater reuse (Edwin, Gopalsamy & Muthu, 2012; Friedler, Kovalino, Ben-Zvi, 2006) however this discussion is technically deep and varied according to specific environments, water flows, and chemicals present. The researcher notes this developing line of inquiry but will not go into depth into its current state.

alter those behaviors for a specific outcome (i.e. the reduction of freshwater use in an arid environment).

Graywater can be defined as, "wastewater that originates from residential clothes washers, bathtubs, showers, and sinks but does not include wastewater from kitchen sinks, dishwashers and toilets" (Roesner, Qian, Criswell, Stromberger, & Klein, 2006. P. E-S1). The RGWO, in short, attempts to use this water to reduce the amount of potable water used for outdoor activities while keeping water 'on site' rather than having waste water funneled back into a water treatment site.

Climate-Adaptive Policies (CAPs)

Numerous academic fields are addressing urban adaptation and climate change transition, carbon reduction initiatives, and sustainable or socio-ecological resilient city movements. One thing all these movements have in common is that their efforts require shifts in both social behavior and built environment planning. Social-ecological resilience refers to the ability to adapt or transform social-ecological systems in the face of change in ways that continue to support human needs (Chapin et al. 2010, Biggs et al. 2015).

How a city plans its future depends, in part, on a city's ability to develop policies and processes that position that city for transition through more than one top down governmental channel of information (Arnold, 2008; Pahl-Wostl, 2006, Geels & Schot, 2007). Many cities are becoming interested in developing policy responses to future climate change-induced social and ecological challenges (Evans, 2011), (or what this paper terms "Climate-Adaptive Policies" or CAP's as defined on page 2). The uncertain repercussions of climate change are encouraging ‘new techniques of governance’ to be considered in urban sustainability planning (Hodson & Marvin, 2007, p. 303).

In a 2013 article in the *Environmental Law Reporter* by Columbia University Press, resilience scientists Lance Gunderson and Craig Arnold explore the relationship between social-ecological resilience, law and policy. They suggest a new paradigm called ‘adaptive law’ for approaching policy designs related to climate change, the goal of which is, “to replace features of the legal system that are rigid, ignore interrelationships among social and ecological systems, emphasize front-end prescriptive rules, and generally are ill-equipped to adapt to rapid, unexpected change*”* (Arnold, 2008, p. 251). Proponents of adaptive law encourage a shift towards distributed governance authority, multi-level civic engagement and resource management by including stakeholders at multiple scales of a management endeavor, minimizing the risks if any single action or approach fails. Under adaptive law, states and cities can play a role in shaping land use, water management, and local environments through policy experimentation (McFadgen & Huitema, 2017). Adaptive law must acknowledge that social-ecological systems are complex systems with stakeholders often acting in unplanned ways that can significantly influence the outcome of the law itself (Levin et al. 2013). Or as Folke and colleagues (2017) summarize: “Hence, the properties of complex adaptive systems change because of the interplay between the adaptive responses of the parts (or agents) and the emergent properties of the whole” (p. 2).

TABLE 1. Conceptual Diagram of Adaptive Management and Policy

Relation of Concepts	**Description**	**Reference**

Adaptive Management	A management process that responds to rapid, unexpected change by incorporating project feedback and adaptation into the management design.	*Swanson et. al, 2009; Pahl-wostl, 2007*
Adaptive Law	Laws or Policies created to be responsive to rapid, unexpected change, characterized by distributed governance authority, multi-level civic engagement and resource management by including stakeholders at multiple scales of a management endeavor.	*Arnold, 2008*
Transition Governance	Transition governance emphasizes the need for purposeful actions to guide changes in how society governs its natural, cultural and built resources. Transition governance sets goals and objectives that move the systems toward new more sustainable or resilient states.	*McFadgen & Huitema, 2017*
Climate-adaptive Policies (CAPs)	Policies that operate within the umbrella of adaptive management and adaptive law but designed to achieve a specific goal or outcome related to resource management and climate change. CAP's act as "pathways" to create more climate resilient cities.	*Avari et. al., 2006). 2017*

Climate-adaptive policies (part of larger adaptive management) refers to a framework for connecting policy strategy and research to design "pathways" to create more climate resilient cities (Avari et. al., 2006).

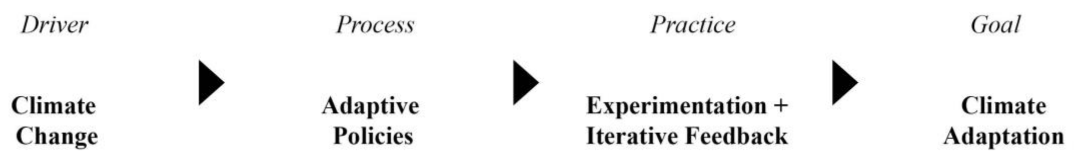


Figure **2**: Climate Change Governance and Adaptation

(Adapted from Figure 1, Evans, 2011).

These CAP's can be put into place to achieve a specific 'sustainable' goal or outcome. Across the U.S. and internationally, there are examples of cities adopting laws aimed at transitioning towards more resilient social-ecological systems (Broto & Bulkeley, 2013; Folke, 2006), resulting in local climate action plans including tree canopy ordinances, wetland management, watershed overlay zoning, riparian buffer zones, among others (World Bank, 2011, Arnold, 2008). Sustainability and resilience transitions are becoming an important concept guiding the management and stewardship of urban natural resource systems, and governance is a key driver of those transitions (Leach et al. 2010, Markard et al. 2012).

Frameworks for understanding the role of experimentation in developing urban climate resilience are well-established in the fields of landscape architecture, community planning, and urban ecology (Arnold, 2008; Geels & Schot, 2007; Karvonen & Bas Van Heur, 2014, Evans, 2011). Well known examples in Urban Ecology include the Baltimore, Maryland and Phoenix, Arizona Long Term Ecological Research (LTER) sites funded by the National Science Foundation. The LTER model approaches cities as Social-Ecological-Systems and engages with cities like field laboratories, focusing on adaptive learning and providing localized research on ecological systems (Evans, 2011). While the LTER model focuses on socio-ecological resilience, the concept of using the city and its' policies as embedded experiments is a valuable consideration for other cities.

While government can play an important role in identifying needed behavior changes over time, it must also find a way to effectively engage with individuals and organizations and social groups to facilitate and remove barriers for long-term behavior change. Some researchers have termed this governmental effort at engagement 'reflexive' or 'adaptive' governance, which:

> Acknowledges that governing activities are entangled in wider societal feedback loops and are partly shaped by the (side-) effects of its own working. It incorporates such feedback by opening problem-handling processes for diverse knowledge, values and resources of influence in order to learn about appropriate problem-definitions, targets and strategies of governance for sustainable development." (Voss & Kemp, 2005).

The emphasis on both individual behavior and policy design highlight the need to approach CAPs with the key users (or stakeholders) in mind.

CAPS as Experiments

"It is one of the happy incidents of the federal system that a single courageous state may, if its citizens choose, serve as a laboratory; and try novel social and economic experiments without risk to the rest of the country"
(U.S. Supreme Court Justice Louis D. Brandeis, quoted in Arnold, 2008, p. 255).

The shift towards adaptive management could be defined as "learning to manage by managing to learn" (Pahl-wostl, 2007, p.49). If cities move toward a management-as-learning approach to both water management and other policies focused on sustainability or resilience, there is the potential to explore and monitor policy initiatives that could be scaled up or adapted to other localities. Although in many cases, interventions (political, physical, ecological) are very much location specific, this does not necessarily preclude said information from being valuable to other localities facing similar problems. As Secord (2004) states in his article *Knowledge in Transit*, "It is not so much a question of seeing how knowledge transcends the local circumstances of its production but instead of seeing how every local situation has within it connection with and possibilities for interactions with other settings." (p. 664) This paper approaches the Residential Gray Water Ordinance as an example of one CAP that could be treated as an 'experimental node,' the monitoring of which could be useful for other municipalities taking similar measures.

According to Holling (1993), adaptive management takes place in two phases: 1. Institutionalizing a framework into which intentional policy interventions may be implemented, and 2. the process of monitoring the various ways a system responds to policy "probe" interventions that have been enacted. These "probes" may take the form of innovative policies that are tested out in one region or locality (like the RGWO for example). As cities create policies to help them adapt to climate change-related issues, it is therefore important to monitor the success or failure of a policy so that it can be better implemented in the future. By implementing varied policy treatments and comparing their results, cities can test hypotheses about the behavior of complex systems at a localized scale (Avari et al., 2006). As Avari and colleagues explain:

> Experimentation in this sense goes beyond management through trial and error and casual observation; it is structured and theoretically driven, designed to elicit specific responses from systems under study such that new knowledge can be incorporated systematically into future treatments (Avari et al., 2006, p. 218).

CAP efforts can approach policy interventions as experimental forms, or 'experimental nodes', that should be monitored and evaluated to both improve performance and spread useful knowledge. Local policy makers can seek out new ideas by exploring ways other cities have dealt with analogous or similar concerns (as in the case of the Los Angeles water conservation ordinance discussed later). Most CAP's have been designed for national or state levels, however local and regional policies will also need to be made to meet wider government regulations and to deal with location-specific changes in climate and resource availability.

Just as landscape architects and planners might monitor the implementation of green infrastructure to assess its performance in relation to preexisting infrastructure, urbanities can design experimental CAPs involving human behavior and the built environment and monitor policy success. In order to do so, urban areas must take in active feedback about social and environmental changes that impact their region and begin developing design interventions and monitoring systems intended to respond to those environmental changes. This paper approaches the RGWO as an example of one such CAP that could be treated as an 'experimental node,' the monitoring of which could be useful for other municipalities taking similar measures.

Los Angeles CAP example. CAPs could be used to address a range of policy goals in both climate mitigation (i.e., emissions reductions, farming practices and forestry, protecting biodiversity, food-supply insecurities) as well as adaptation (e.g., planning and design to address climate change impacts due to acknowledging changes in temperature and precipitation patterns, needs for water conservation, ecosystem collapse, pollution etc.) (Arnold, 2008). For example, cities wishing to understand the impacts of altering building construction practices to reduce residential water use could look to the water conserving building ordinance passed by city of Los Angeles in April, 2016. The building ordinance was a result of Mayor Eric Garcetti's October 2014 Executive Directive on Water Conservation to Address the Ongoing Drought, which directed the Los Angeles Department of Building and Safety (DBS) to, "compile and propose to City Council a list of potential building code changes for new and retrofitted buildings," features code changes that require new buildings in Los Angeles to reduce potable water use by 20 percent indoors through the installation of more efficient plumbing fittings and fixtures. It is estimated that the available graywater is roughly 25% of the city's water demand. The city conducted a cost-benefit analysis of onsite graywater recycling in single and multifamily homes in the Los Angeles, California area. The conclusions were as follows:

> Graywater recycling reduces potable water demand by 27 and 38% in single-family and multifamily homes, respectively. At a participation level of 10%, Los Angeles will be able to reduce water supply and treatment-related energy by 43,000 MW·h/y, potable water demand by 2%, and wastewater treatment load by 3%. Amending local building codes to require new construction to include plumbing to divert graywater for reuse can lower retrofit costs. (Yu et. al., 2015).

One portion of the ordinance relates to graywater, calling for the installation of alternative waste piping to allow graywater from the clothes washer, bathtub, showers, and bathroom/restroom wash basins to be used for outdoor irrigation systems. (Los Angeles Municipal Code, 2016). The Los Angeles building ordinance could be considered an example of a CAP much like the RGWO that could be monitored to varying degrees of success, the findings of which could be synthesized and made available to other legislatures hoping to achieve similar results.

CAPs and Environmental Psychology

The RGWO in Arizona is one example of a policy attempting to rethink how the built environment interacts with water resources and human behaviors and alter those behaviors for a specific end outcome (i.e. the reduction of freshwater use). The use of graywater requires the interaction of individuals with physical/structural systems (therefore a human-environment interaction), which is why the researcher believes the field of environmental psychology provides an appropriate lens through which to analyze the RGWO. By analyzing the relationships between the physical environment, policy design, and stakeholder experience at varying steps in policy implementation, we can begin to understand the complexity involved in identifying the limiting or enabling factors in the policy's implementation. Patterns of behavior cannot be separated from the physical setting in which they take place (Pelletier, Lavergne, & Sharp, 2008, Gifford, 2008) and Environmental Psychology acknowledges that physical environments provide context clues, limitations, and instructions that impact human behavior.

Graywater systems are embedded into the architecture of buildings and the surrounding landscapes; both social actors and structural systems are required to work together to successfully implement a graywater system and for it to be successful in achieving the goal of water reduction used (Domenech and Sauri, 2010). Gleick (2003) advocates a "soft path" to build greater flexibility in water management regimes to deal with climate uncertainty:

> A transition is under way to a 'soft path' that complements centralized physical infrastructure with lower cost community-scale systems, decentralized and open decision-making, water markets and equitable pricing, application of efficient technology, and environmental protection." (p. 1524).

Reusing water at the residential scale represents one such "soft path" towards greater flexibility as reusing water from residential buildings is becoming more common as a way to reduce potable water use in urban areas. However, decentralizing water reuse means that users (i.e. homeowners, renters) must take on individual responsibility to successfully shift towards decentralized water management (Domnech & Saurí, 2010). This interaction between individuals, technology, environment and policy is why considering social interactions in adaptive policy design is so important, and why considering the ultimate experience of different stakeholder actors is useful. Ecological models can be used to better understand the impact of different managerial and social policies at both the macro- and the micro-level, shedding light on barriers to change in social–ecological systems (Moffatt & Kohler, 2008).

Examining User Experience through an Ecological Systems Model

This paper uses an ecological model to analyze the role of local graywater users/graywater stakeholders in implementing a climatic adaptive policy like the RGWO that involves the engagement of multiple stakeholders in achieving socio-technical transition. Ecological models of behaviors are frameworks of nested social interaction, representing changes in social or physical environments through multi-level analysis ranging from high-level policy to tangible design (Moskell & Broussard, 2013). As has been explained previously, CAPs require the engagement and cooperation of multiple stakeholder actors (or users), therefore the ecological model is an appropriate framework for examining the complex spheres of influence in policy decision-making.

Stemming from Urie Bronfenbrenner's original Bioecological Framework for Human Development (Bronfenbrenner, 1979), ecological systems theory claims that the contextual ecological systems must be considered when studying human development and behavior (Bronfenbrenner & Morris, 2007, Bronfenbrenner & Evans, 2000). Literature on policy implementation has used similar models, for example, Oran Young (2002) used the terms macro, meso, and micro to describe varying (vertical and horizontal) scales at which policy development activities can take place and intersect. Hodson and Marvin (2010) put it this way when talking about cities shaping socio-technical transitions,

> There are multiple scales of governance action, with differing sets of power relations operating in the relationships between these scales of action and these power relations between different scales of action are variably constituted and organized in respect of different cities" (p. 481).

Questioning critically these relationships between scales allows us to conceive of cities not merely as sites for receiving climate-adaptive policies, but also potentially as contexts for urban transition.

A variety of ecological models have been used in environmental and community psychology to evaluate how individual behavior both affects and is affected by the social and physical environment, and how behavior both shapes and is shaped by multiple levels of influence. The ecological model McLeroy and colleagues (1988) employed categorizes behaviors and their influencers into five categories: individual, interpersonal, organizational, community, and policy.

TABLE 2. An Ecological Perspective: Levels of Influence

Levels of influence	**Description**
Individual	Individuals and characteristics that influence behavior on a direct level: beliefs, values, education
Interpersonal	Interacting individuals, interpersonal processes, with primary groups including family, friends, peers
Organizational	Rules, regulation, policies, and informal structures impacting the individual
Community	Formal and informal cultural and social networks, associations, and neighborhoods surrounding the individual

Policy	Policies and regulations affecting individuals

Source Adapted from McLeroy et al. (1988).

In their article on adaptive water management and social learning, Stokols et al. (2003) discuss the importance of understanding the complexities of human-environment-technology systems for more integrated water management. Due to this complexity, there is uncertainty in the understanding of water use system elements and interactions, including interruptions, feedback loops, and delays that generate those trends. Multiple stakeholders (or users) have different ideas about the causes of problems, producing a variety of appropriate and legitimate solutions which is why consulting them about their experience with the policy design could strengthen and improve it.

Understanding the potential for multi-level interventions could prove critical for policy adaption (Stokols et al. 2003). Users of graywater may need to alter habits and provide maintenance to ensure smooth operation of water reuse systems. As Domnech and Saurí (2010) explain: “tradeoffs in terms of comfort and behavioral practices are necessary to attain global and local environmental benefits” (p. 54). Social, cultural, and physical design elements can be key determinants in the success or failure of new policies and technologies. Therefore (as relates to the ecological model), it is important to consider how these factors are interrelated (Pahl-Wostl, 2007). This thesis uses the term ‘user experience’ to refer to the investigation of users (of products, places, services etc.) and their needs or requirements in a given ‘user’ context. The point of user experience research is to add context and insight into the process of designing the user experience (Nunnally & Farkas, 2016).

Graywater and Sustainable Water Management

When situations are characterized by variability, uncertainty and change, conventional planning scenarios provide little guidance regarding future needs and conditions.
-Moench et al. 2003, p. 9

Thus far, we have discussed CAPs and how they can be part of the transition management process as cities attempt to become more resilient in the face of climactic variation and resource shortages. This research uses the Residential Gray Water Ordinance as CAP case study. This section discusses what graywater is, and how the RGWO relates to planning for climate change.

Overview of Graywater Systems in the U.S. Graywater in the U.S. makes up roughly 45-50% of household water use (DeOreo et al., 2016; Criswell & Stromberger, 2006). Indoor water use in nine North American cities is, on average, 138 gallons per household per day (gphd), or 59 gallons per capita per day (DeOreo et al., 2016). Using household water for outdoor irrigation is becoming increasingly accepted in the United States. While the amount of water used for outdoor irrigation varies according to landscape type, management practices and region, landscape irrigation can account for 40 to 70 percent of household water use. Hilaire and colleagues (2008) call for the efficient use of irrigation water in urban landscape as a primary focus of water conservation, noting that outdoor irrigation is an area in need of more efficient conservation practices.

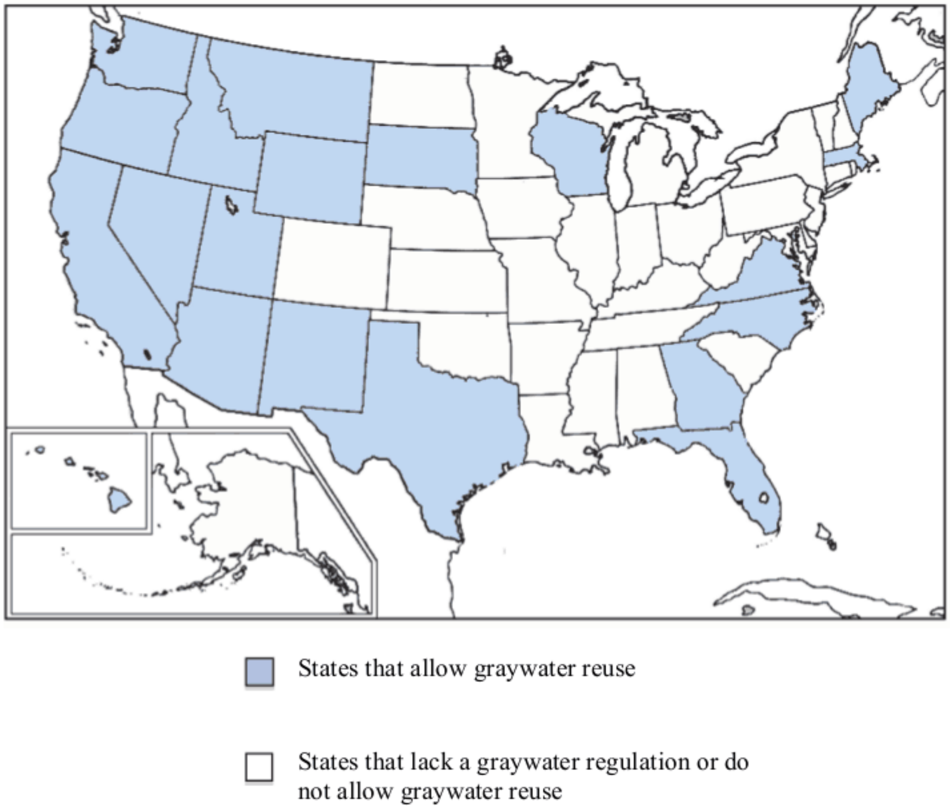


Figure 3. States Allowing the Use of Graywater. Sharville (2013).

Retrieved from: https://greywateraction.org/greywater-codes-and-policy/

Almost half of residential gray water has the potential to be reused for outdoor irrigation (DeOreo et al., 2016). Crisswel and Stromberger (2006) note that,

> Given an average household population of 2.6 persons in the U.S., there are approximately 90 gallons of graywater per day per household available for outside use. This supply is not sufficient to irrigate an entire yard landscaped in bedding plants and bluegrass, but a homeowner with a 2,500 ft2 house on a 1/4 acre lot could irrigate about 1/2 of the yard with graywater if xeriscaping is used. (pg. 1)

In the U.S. Southwest, much of household water is used for outdoor landscaping (60% in Phoenix, AZ and 40% in Tucson, AZ) where xeriscaping is more common (xeriscaping is landscaping with native desert plants and little or no lawn) (Eden, Gelt & Pitzer, 2007). Residential graywater reuse has the potential to significantly reduce the amount of potable water used for irrigation. In Arizona, total municipal water use is at 20% or 1.6 million acre-feet, and of that 20%, the majority (60%) is used for outdoor landscape irrigation (Eden, Gelt & Pitzer, 2007). Many new residential homes in Arizona are xeriscaped to promote water conservation. While conservation efforts like this have reduced the amount of water used for irrigation, as the population continues to grow, so will municipal water use.

Graywater Regulation. In the United States, there are no national guidelines mandating the regulation of graywater use; states, counties and cities are responsible for the governance of graywater use (Tufvesson, 2009). As of 2013, twenty states had some form of graywater reuse, but Arizona and California are considered leaders in promoting graywater reuse because they use a tiered system of regulation in proportion to the potential health risks, making it easier for individuals to recycle small amounts of water (Sharvelle et al., 2012). Arizona's laws were not always so accommodating. A 1999 survey of the Tucson area by the Water Conservation Alliance of Southern Arizona, or WaterCASA, and the WRRC discovered that 13% of residences surveyed were using graywater in some capacity, usually via a hose or pipe extending from a clothes washer to landscape plants. The finding was significant because, when extrapolated to the entire state, meant that about 200,000- 300,000 home graywater systems in Arizona were operating without a permit, which was then illegal. In 2001, the Arizona Department of Environmental Quality began allowing households to reuse graywater on a small scale without a permit if common-sense best management practices were followed (See Appendix for full list of best practices). This 'soft permitting' approach makes it much easier for people to reuse water, relying on education and outreach rather than labor intensive permitting practices. Other states like California and New Mexico have developed similar approaches to graywater regulation (Water Resources Research Center, 2007). However, inconsistent plumbing codes and legislation have hindered the development of standardized technological approaches for promoting the reuse of graywater (Little, 2000).

Retrofitting existing homes to either store and redistribute graywater or use treated graywater for toilet flushing poses a large financial barrier for adoption. However, new homes can (usually) easily be built with dual plumbing systems or gravity-based laundry-to-landscape systems for graywater collection and use at a low marginal cost. Luthy and colleagues (2016) estimated that systems incorporating graywater from bathtubs, showers and bathroom sinks may provide water savings up to 19,000 gallons (72,000 liters) per household per year (assuming 2.5 persons per household). Hence, Tucson's RGWO is a progressive pilot policy worthy of examination to help inform other cities and states striving to integrate graywater practices into their long-term water resource plans.

Although it will not be discussed in depth here, internationally, graywater reuse is also receiving attention as centralized urban water systems try to respond to environmental and economic pressures, especially in arid regions in Australia (Marks & Zadoroznyj, 2005), Spain (Domnech, & Saurí, 2010) Africa, Israel and the Middle East (Leas, Dare, Al-delaimy & Mena, 2014). The cost of treatment and the ambiguity around the health-related safety of gray water and treated graywater remain some of the biggest obstacles for graywater reuse.

Brief History of Arizona Water

Arizona has extreme fluctuating weather patterns, with both severe regional floods and long droughts. A changing climate in tandem with growing residential water demands is forcing planners to devise ways to stretch supplies while restoring the state's water resources.

Population. The majority of Arizona's 7 million people lives in the Sonoran Desert (including Tucson and Phoenix). Despite its desert landscape, Arizona is one of the most urbanized states in the country with the largest urban areas being Phoenix (1,615,017) and

Tucson (530,706) (Arizona State Demographics, 2017). The population increased by roughly 1 million residents in the past five years and may reach as many as 9.5 million by 2025 (Anderson et al., 2008). New residential development has surged to meet this population demand, causing challenges for state and local officials trying to balance water resources with economic viability.

Temperature and Rainfall. Annual rainfall in Arizona ranges between 3 and 15 inches. Tucson receives an annual average 12 inches of rain, with the majority of it falling during summer monsoons from July through September (US Climate Data, 2017). It is difficult to know what the impacts of climate change might be for the Southwest's future water supplies. Average temperatures in the Southwest have risen by 2-3 degrees Fahrenheit, with predictions of a 9-degree Fahrenheit increase during the 21st century.

Water Use. Arizona uses about 8 million acre-feet, or 2.3 trillion gallons, of water each year (Eden, Gelt, & Pitzer, 2007). Potable water demand is projected to increase from about 104,000 acre-feet in 2012 (actual) to a range between 120,000 to 145,000 acre-feet per year by 2030. By 2050, the potable demand will likely range from 147,000 to 178,000 acre-feet per year (City of Tucson Water, 2012).

Roughly 54 percent of the water used in Arizona is surface water, with vast groundwater aquifers providing another 43 percent. Recycled water, which is wastewater treated to suitable reuse standards, comprises about 3 percent of the Arizona's water supply but its use is growing. Agricultural industries use roughly 75% of Arizona's water, the rest is primarily used by residents (20%) and industry (5%) (Eden, Gelt, & Pitzer, 2007).

Water Resources. Arizona's surface water resources come from the Colorado River, the Salt, Verde, Gila, San Pedro, Bill Williams, Santa Cruz, Little Colorado and Agua Fria rivers.

The Central Arizona Project (1922) is Arizona's largest water storage and distribution project, delivering Colorado River water to cities and water utilities, agricultural users, Native American communities and underground water storage (recharge) projects (ADWR, 2017). A 336-mile canal extending from the Colorado River to central and southern Arizona, terminating south of Tucson, bringing water to 4 million people and 300,000 acres of irrigated farmland in Central. However, public officials and scientists predict the Colorado River may run short due to drought and increasing population growth, estimating a 25 percent chance the river will not be able to meet all the anticipated demands between 2020 and 2025.

Groundwater. Arizona has historically pumped more groundwater than can be naturally recharged. Although estimates of total groundwater in Arizona range up to 900 million acre-feet, these estimates do not translate to the amount of water really available, which varies in location, depth and quality. In some basins, the amount of water withdrawn from aquifers exceed the amount of recharge by a factor of three or more. The Groundwater Management Act of 1980 designated largely urban active-management areas, or AMAs, which were required to wean themselves from groundwater pumping. Four of Arizona's five AMAs must diminish reliance on groundwater to the point that recharge and extraction are in rough balance by 2025. Today Arizona has one of the largest state groundwater recharge programs (Eden, Gelt, & Pitzer, 2007)

The Assured Water Supply (AWS) Program, a feature of the Groundwater Management Act, requires new residential developments to demonstrate sufficient water — including substantial supplies from renewable sources — to meet the needs of the new residents for 100 years (ADWA, 2017). Meeting this requirement is challenging given the projected population growth expected over the next five years. According to the Eden, Gelt and Pitzer's report for the

Water Education Foundation and Arizona University Water Resources Research Center,

> Prior to plotting a new subdivision, a potential developer must demonstrate that the water supplies available will meet applicable water quality standards and water must be "physically, continuously and legally available for 100 years." In addition, the applicant must show the financial capability to construct the necessary infrastructure. Underground Water Storage, Savings and Replenishment Act addressed this issue for projects within AMAs, providing legislative protection to the people who stored the groundwater. (p. 14)

Approximately 2 million acre-feet of water storage has been created in permitted recharge facilities since 1994.

Water Reuse. One of the first states to consider graywater as an alternative source of water, treated waste water currently constitutes about 3 percent of the state's water supply, with more being used to recharge groundwater aquifers (Eden, Gelt, & Pitzer, 2007). In the arid Southwest, 60 to 70% of municipal water use occurs at a residential scale, with most water being used outdoors for landscaping and pools (Holway, 2009). By reusing residential graywater, municipalities could significantly reduce water demand and energy costs associated with landscaping and waste water treatment.

In Tucson, where low water use landscaping is more common, outdoor watering accounts for only about 40 percent of residential water use (Eden, Gelt, & Pitzer, 2007). The city engages in numerous efforts to conserve water, including rebate programs to replace old, wasteful appliances and sprinkler systems with newer, more efficient models. Tucson also runs a water reclamation program that is used to supply businesses (like golf courses) with irrigation water. Local conservation officials continue to stress wise water use, however there are infrastructural and behavioral changes that take longer to instill.

Arizona's Residential Gray Water Ordinance

On September 23, 2008, the City of Tucson adopted a Residential Gray Water Ordinance (No. 10579) put into effect July 1, 2010 mandating the following:

1. All new single family and duplex residential dwelling units shall include either a separate multiple pipe outlet or a diverter valve, and outside "stub-out[3]" installation on clothes washing machine hook-ups, to allow separate discharge of gray water for direct irrigation.
2. All new single family residential dwelling units shall include a building drain or drains for lavatories, showers, and bathtubs segregated from drains for all other plumbing fixtures and connected a minimum of three (3) feet from the limits of the foundation, to allow for future installation of a distributed gray water system.
3. All gray water systems shall be designed and operated according to the provisions of the applicable permit authorized by ADEQ under the Arizona Administrative Code, Title 18, Chapter 9 (City of Tucson, 2010). Updates to the RGWO were made on July 9, 2013 to include minimum gray water fixture requirements, to encourage the use of gravity fed systems, and to mandate appropriate repercussions for the negligence of the ordinance. As most urban buildings are plumbed to route all wastewater to the sewer, retrofitting a home for graywater reuse can be costly (Lancaster, 2006). RGWO makes it easier and less costly for residents to reuse graywater and conserve potable water. Although over 2,000 homes have been built after the ordinance, there is no information available on whether or not the ordinance has facilitated graywater reuse.

[3] Stub-outs are the graywater collection pipes extending to the outside of the house that are capped but accessible for future use (Ludwig, 2015).

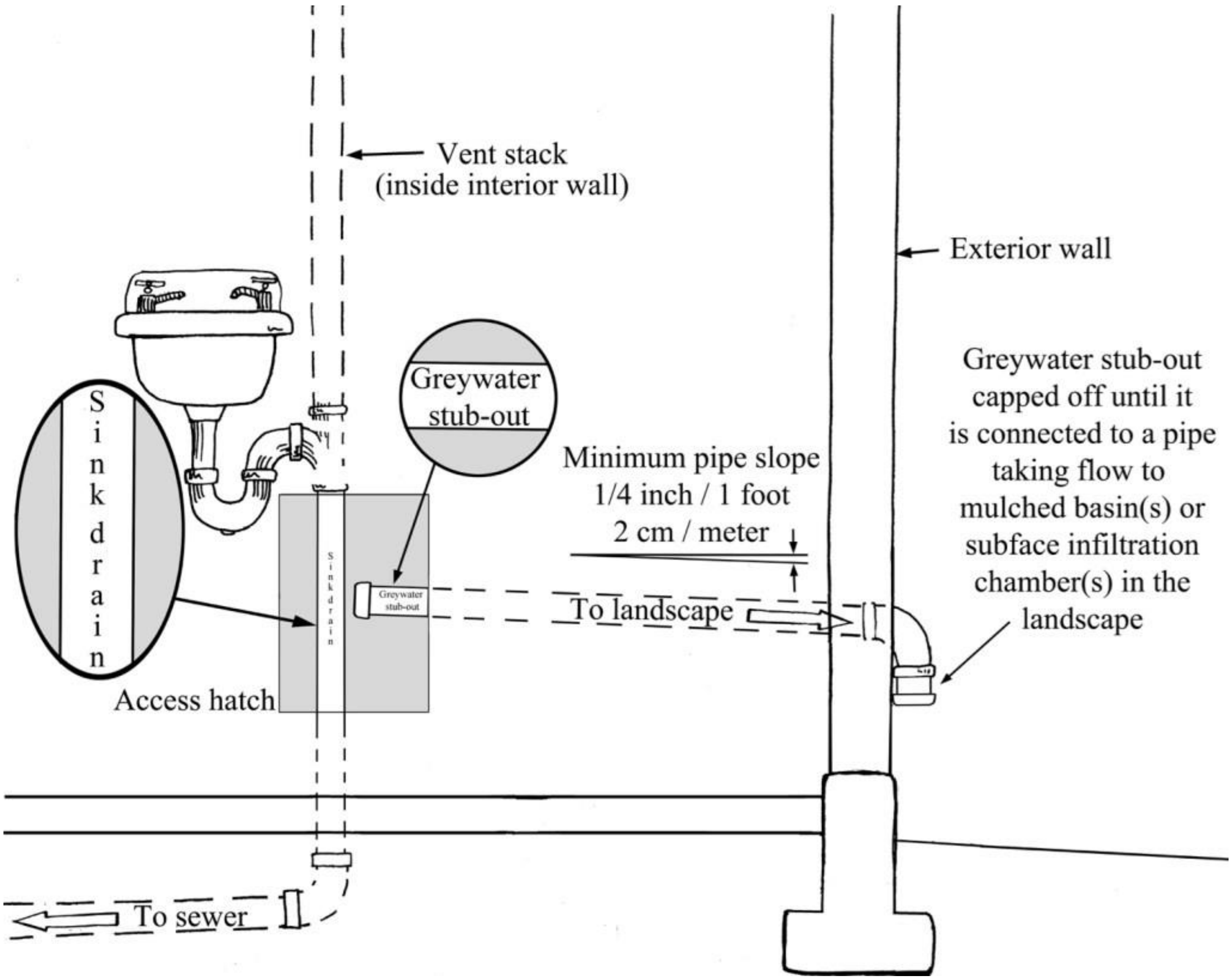


Figure 4. A stub-out not yet connected. Lancaster (2008).

Retrieved from: https://www.harvestingrainwater.com/greywater-harvesting/greywater-harvesting-stub-outs/

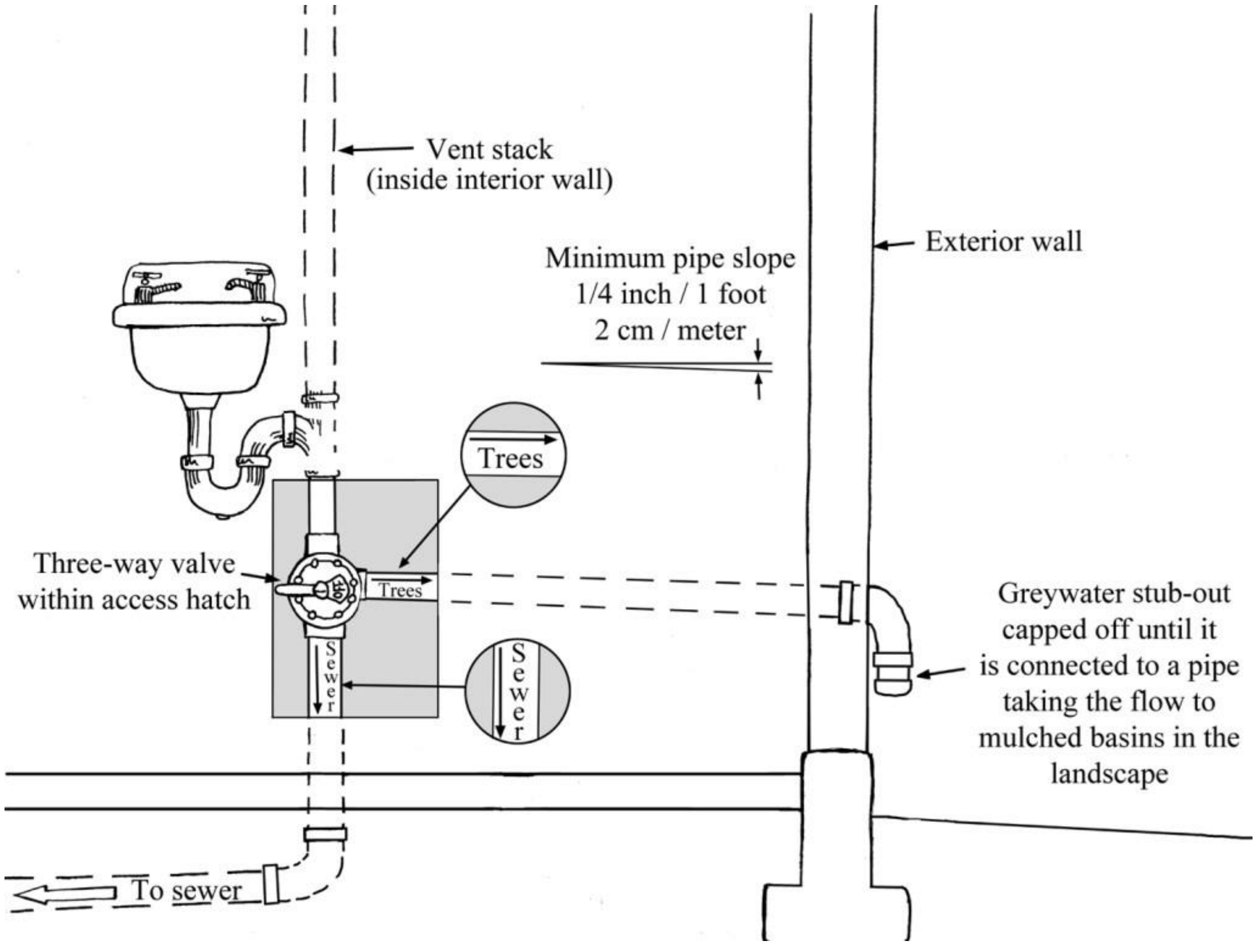


Figure 5. Stub out connected to drain pipe but not to landscape.

Lancaster (2008). Retrieved from: https://www.harvestingrainwater.com/greywater-harvesting/greywater-harvesting-stub-outs/

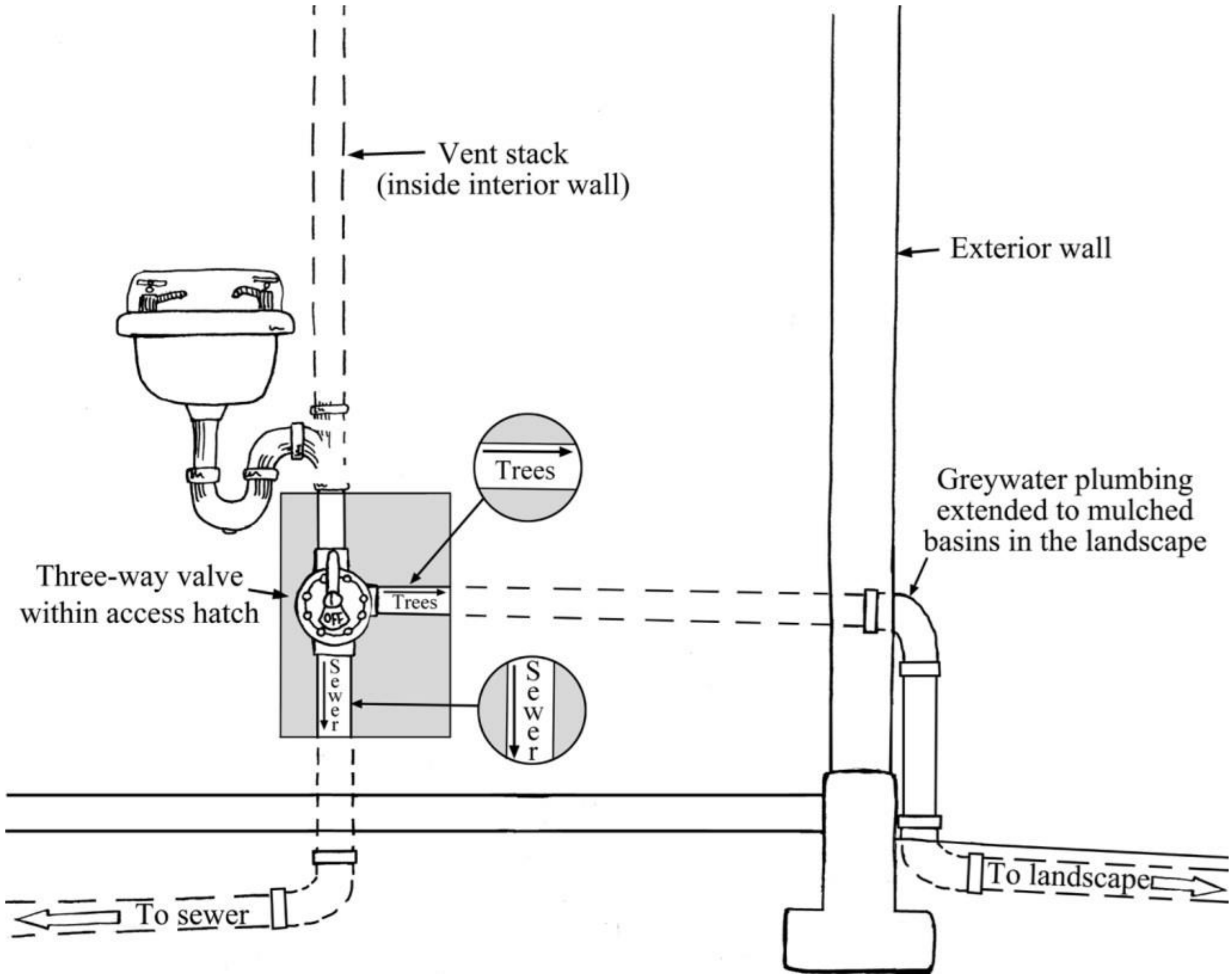


Figure 6. Stub out connected to drain pipe and to landscape.

Lancaster (2008). Retrieved from: https://www.harvestingrainwater.com/greywater-harvesting/greywater-harvesting-stub-outs/

Government agencies have recently advocated for the use of wastewater as a water conserving strategy (EPA, 2016c), however movements towards graywater reuse will likely be initiated at the state, rather than the national level. Therefore, policies initiated at the state and regional level (like the Residential Graywater Ordinance) are essential to widespread adoption of distributed graywater management (Yu et al., 2013). For many arid climates, reusing graywater has the potential to promote sustainable living by supporting decentralized water management, and reducing the demand for potable water, reducing municipal energy use, and household water costs (Congressional Budget Office, 2002, Consortium for Energy Efficiency 2007). Tucson Arizona's RGWO makes it easier and less costly for individuals to reuse graywater. However, there is currently not any widespread data on how well the policy has facilitated residential graywater use, as was intended.

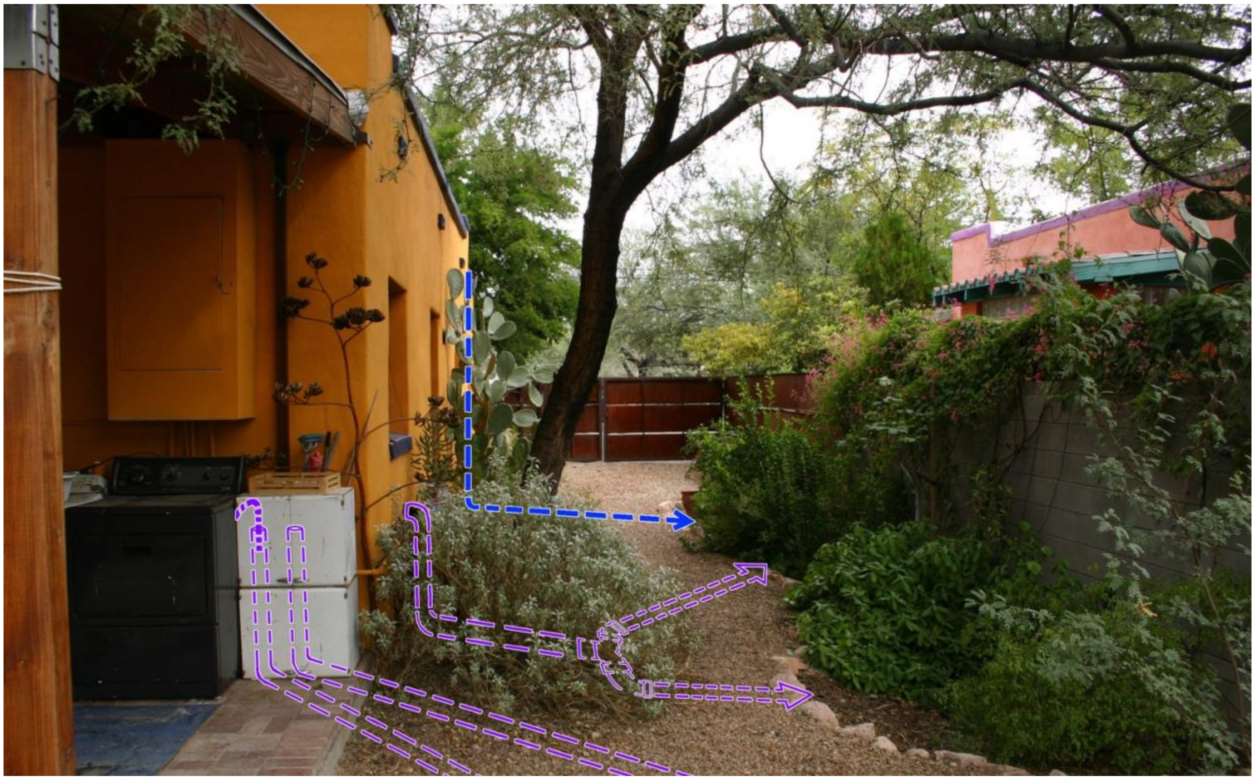


Figure 7. Demonstration of graywater (purple) and rainwater (blue) piping into covered mulch basins in the landscape. Lancaster (2008). Retrieved from: https://www.harvestingrainwater.com/greywater-harvesting/

Summary

Urban areas face various resource strains in adapting to climate change. Adaptive management, through things like Climate-adaptive Policies, can provide ways for cities to transition to more resilient policies. However, adaptive management requires that governments be willing to be reflexive, taking in feedback for iteration, as they design policies to address complex social-ecological challenges. Acknowledging the fundamental role that stakeholders and ‘end users’ play in implementing said policies is imperative to achieving the desired policy outcomes. Climate-adaptive policies could benefit from taking a user-experience perspective when evaluating and planning policies. This research explores the RGWO as an example of a CAP, striving to evaluate the effectiveness of the policy by asking end users about their experience reusing water from their homes, while also offering an ecological framework for considering the barriers to reusing water at a residential scale.

CHAPTER 2

RESEARCH METHODS

Research Questions

This research aimed to answer the following questions were addressed through two studies as summarized in Table 3.

TABLE 3. Research Questions and Analytic Strategies.

	Research Questions	Analysis	Study 1	Study 2
RQ1	Based on stakeholder interviews, what are the multi-level user-experience barriers to reusing residential graywater in homes built after the RGWO?	Qualitative insights		
RQ2	Did the 2010 RGWO encourage residential graywater recycling in Tucson, Arizona?	Descriptive statistics		
RQ3	Are there individual-level predictors of graywater reuse practices?	Statistical Analysis: Two-step cluster analysis, Binomial regression analysis		

Study 1: Stakeholder Insight

Study 1 addressed one research question:

Research Question 1: Based on stakeholder interviews, what are the multi-level user-experience barriers to reusing residential graywater in homes built after the RGWO?

In-depth guided interviews were conducted to gain insight into how different stakeholders involved with the RGWO: (1). Viewed the CAP (meant to enable residential water recycling and reduce potable water use) and (2). what barriers they perceived in implementing the policy.

Method

Snowball sampling (in which each participant suggests or names other potential participants) was used to gather participants whose professional fields are related to or have been impacted by, the RGWO. The sampling began with fourteen individuals publically recorded as part of Tucson's Graywater and Rainwater Stakeholder Group and the Watershed Management Group. Ultimately, nine semi-structured interviews were conducted with professionals (Two Graywater User Activists, Three Water Educators, One Home Builder, One Water Consultant, One Architect Educator, and One Water Researcher) about their involvement with the RGWO and the nature of their professional and their personal experiences with graywater systems. A digital audio recorder was used to record the interviews when participants consented.

Interviewees were asked about their level of familiarity with the RGWO, their thoughts on the policy, their understanding of how the policy has impacted water use, any perceived barriers to water reuse they have noticed in their respective fields, interventions that they believe would be most helpful in enabling water reuse, and what their thoughts were on how the policy was implemented.

Study 2: Policy Impact Evaluation

The purpose of Study 2 was to evaluate the effectiveness of the RGWO as a CAP: (1). whether or not the revised building standard resulted in more water recycling and (2) to assess people's awareness and interest in using graywater at the residential scale when their homes were designed to support graywater reuse.

Research Questions

Research Question 2: Did the 2010 RGWO encourage residential graywater recycling in Tucson, Arizona?

Research Question 3: What are the individual-level predictors of graywater reuse practices?

Method

A cross-sectional survey (offered in both English and Spanish) was mailed in March-May, 2017 to residents in newly built single-family households approved for construction in Tucson, Arizona after June 1, 2010 (after the Tucson Residential Graywater Ordinance had gone into effect).

Participant Recruitment. Publicly available building permit and address data were collected from Pima County Development Services for newly built single-family houses. All 2,422 households selected for the study resided within Tucson, AZ.

After gaining approval from the Cornell University Institutional Review Board, invitation postcards with instructions on how to access the online Qualtrics survey were sent to participants through the U.S. postal service during the months of March, April, and May 2017. Participants were offered the chance to enter their email address in a raffle to win a $200 visa gift card.

Constructs and Measures

Using Qualtrics survey software, a survey pilot was tested March 2017, with a convenience sampling of 35 participants located in Ithaca, New York. Of those participants, sixteen took the survey twice. This data was used to evaluate test-retest reliability and Cronbach Alpha for the two measures, ensuring that the tests were reliably measuring the same constructs over time. The Cronbach's Alpha's are reported in Table 4, below[4].

TABLE 4. Study 2 Survey Variables

Explanatory Variables	**1. Demographic variables** • Age • Home ownership • Time lived in Tucson • Household income • Educational background • Gender 2. Perceived water conservation norms (3-item, likert scale) 3. Water conservation efficacy (4-item likert scale)
Outcome Variables	1. Graywater Use 2. Graywater Awareness

[4] Test-retest reliability was not of statistical significance for the sample of 16. Because the participants taking the pilot study were not the actual participants, the questions did not fit within their living context. It is possible then that the test retest reliability was compromised by the subject sample and the way questions were interpreted.

- Knowledge of graywater
- Knowledge of stub-out
- Knowledge of graywater legality in Arizona

3. Graywater Interest

Explanatory Variables.

1. *Demographic variables* included age, education, income bracket, gender, household size, number of people in the household, homeownership, length of time living in Tucson.

2. *Perceived water conservation norms* was measured with a three-item scale adapted from the Pro-Environmental Descriptive Norms Scale (Bissing-Olson, Fielding, & Iyer, 2016). This scale measured the pro-environmental norms of important people in the participant's life (Bissing-Olson, Fielding & Iyer, 2016). The three original items were: (1). “Most people who are important to me act in environmentally-friendly ways,” (adapted to “Most people who are important to me care about water conservation”) (2). “Most people who are important to me try to conserve resources,” (adapted to “ Most people who are important to me try to conserve water resources”) and (3). “Most of my friends and peers engage in environmentally-friendly behaviors,” (adapted to “Most of my friends and peers engage in water conserving behaviors”). Participants rated their agreement with each item on a scale from 1 (disagree strongly) to 5 (agree strongly). The Cronbach Alpha was .75 for the original measure, and .78 for the adapted scale used in this research.

3. *Water conservation efficacy* was measured using a four-item likert-scale with five response options (Strongly agree to strongly disagree), adapted from the four-item Environmental Efficacy Scale (Ojala, 2012), which was developed to assess individual and collective water conservation

efficacy. Items included: “I think that I myself can contribute to the improvement of water conservation in my city” adapted from, “I think that I myself can contribute to the improvement of the climate change situation.” In the original scale, two items capture individual self-efficacy, and two items assess collective efficacy. Factor analysis in the original scale revealed one factor with good internal reliability for the original scale (Cronbach alpha = .86). The Cronbach Alpha for the adapted scale used in this research was .76.

TABLE 5. Likert Scales

Perceived Water Conservation Norms Questions	Cronbach Alpha
Most people who are important to me care about water conservation. Most people who are important to me try to conserve water resources. Most of my friends and peers engage in water conserving behaviors. *Adapted from Bissing-Olson, Fielding, & Iyer, 2016.*	.78

Water Conservation Efficacy Scale Questions	Cronbach Alpha
I think that I myself can contribute to the improvement of water conservation in my city. I know there are a number of things that I myself can do in order to conserve water. I believe that together we can do something about water conservation. I am confident that together we can solve the water conservation issue in my city. *Adapted from Ojala, 2012*	.76

Outcome Variables

There were three overarching outcome variables. These are described below and summarized in Table 6.

1. *Graywater use* was measured by asking participants whether or not they reused graywater. The response to, "Do you reuse graywater from your home?" was recorded as a dichotomous, yes (coded 1) / no (coded 0) question but provided participants with the option to explain that they had previously reused graywater from their home but did not at this point. Participants responding Yes were subsequently directed to a section of the survey only for graywater users (see Figure 2).

2. *Graywater awareness* was broken into the following categories:

- 2.a *Knowledge of graywater* was assessed by asking participants whether or not they had heard of graywater before (coded dichotomously as yes (1) /no (0)), and whether or not they had heard of the RGWO before receiving the survey (coded dichotomously as yes (1) / no (0)).
- 2.b *Knowledge of graywater stub-out* was assessed by asking participants two questions: if they knew what a stub-out was (coded dichotomously as yes (1) /no (0)), and whether or not they thought their home had a stub-out (coded as yes (1) /no (0)/ not sure (2))
- 2.c *Knowledge of graywater legality in Arizona* was assessed by asking participants if they were aware that it is legal to reuse graywater in Arizona (coded dichotomously as yes (1) /no (0)).

3. *Graywater Interest* was measured by asking participants how interested they were in reusing graywater from their home (one item). Responses were recorded through a five-point likert (1=Extremely interested – 5=Not interested at all). To create a stronger understanding of the data, responses were collapsed into three categories (Very interested (responses 1 and 2), Somewhat interested (responses 3 and 4), Not interested (response 5).

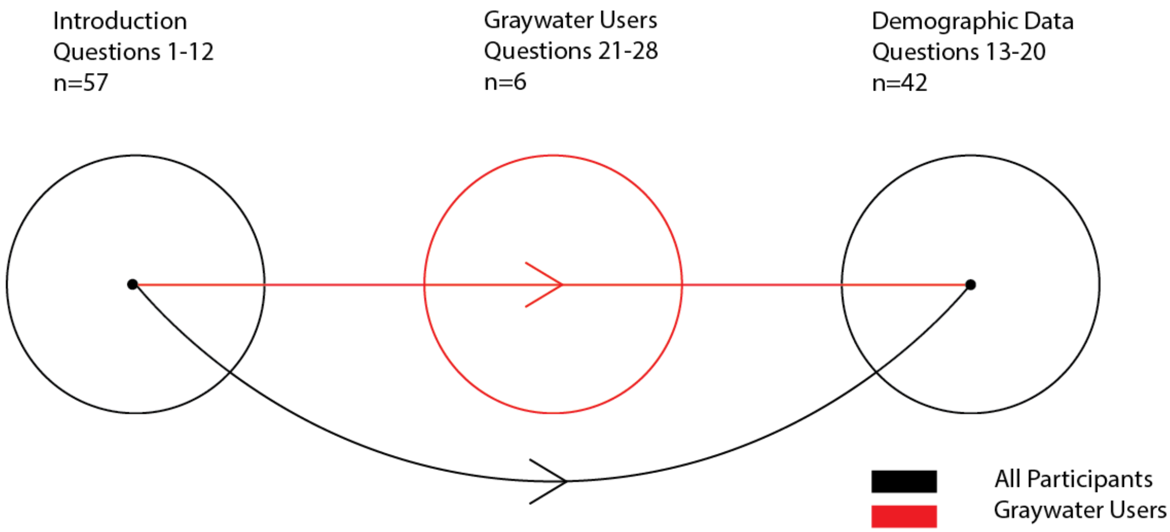


Figure 8. Survey flow

Analytic Strategy

Study 1: Stakeholder Insight

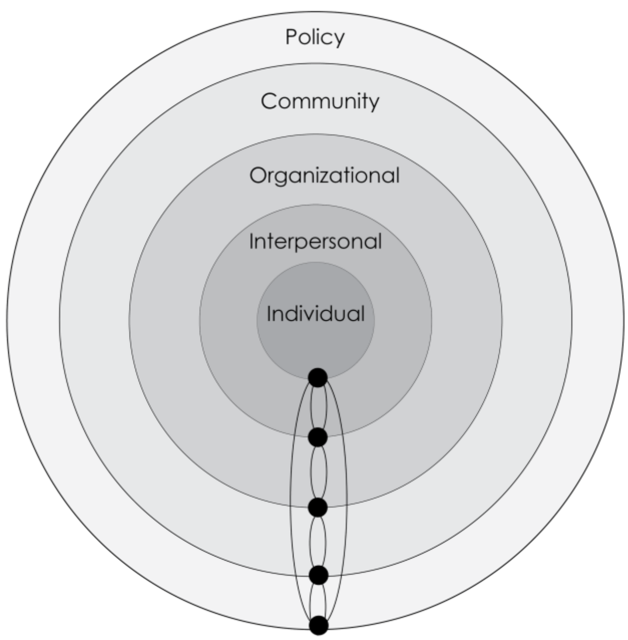
RQ1 Based on stakeholder interviews, what are the multi-level user-experience barriers to reusing residential graywater in homes built after the RGWO?

This question was examined via the in-depth interviews with graywater stakeholders in Study 1. Interviews were transcribed and analyzed using a constant comparative method (Glaser & Strauss, 1967) to combine explicit coding procedure with an analytic procedure for theory development. Data was coded at the paragraph level and sorted into category themes emerging from the data around the use of graywater. Specifically, this research followed Glaser and

Strauss' (1967) description of the four stages of the constant comparative method, namely:

1. Coding transcribed data into categories of analysis
2. Integrating defined categories and their properties
3. Delimiting theory (or explanation).
4. Writing the theory (or explanation).

The data are presented and discussed in the results section according to 12 themes around barriers to using graywater that emerged from the data. The categories are organized and discussed within an ecological model framework to facilitate a better understanding of how behaviors and beliefs are nested within social contexts.



Author's interpretation of McLeroy et al. (1988).
Figure 9. Ecological Systems Model.

Study 2: Policy Impact Evaluation

RQ2. Did the 2010 RGWO encourage residential graywater recycling in Tucson, Arizona?

This question was addressed via the Study 2 survey by asking residents whether they did or did not use a graywater system, the types of systems used, the locations from which water was reused, how well their graywater systems worked, and any perceived barriers to using their graywater systems. The number and percent of graywater users are reported in descriptive statistics.

RQ3. What are the individual-level predictors of graywater reuse practices?

This aim was addressed in Study 2 by collecting information about graywater reuse practices and graywater awareness. A two-step cluster analysis was conducted to identify groups of participants who showed a greater interest in graywater reuse. The purpose of the cluster analysis was to identify the 'clustered features' of respondents who were highly interested and knowledgeable about graywater reuse and compare those features to the other respondents. Binomial regression analysis was used to identify significant demographic characteristics of participants who were interested in and knowledgeable about graywater. A binomial logistic regression is a multiple linear regression analysis used to predict a dichotomous (rather than continuous) dependent variable based on one or more continuous or nominal independent variables (in this case, to predict dichotomous responses to questions about graywater use and awareness).

Binomial logistic regression was used because the questions about graywater use and awareness were recorded as binary categorical variables, meaning a standard linear regression model cannot be used. Logistic regression models for binary response variables (like graywater awareness variables) allows for the probability estimation of the outcome variable (e.g., yes vs. no), based on the values of the categorical and dichotomous explanatory variables (like demographic data).

CHAPTER 3

RESULTS

Demographic Overview

Of the 2,422 participants invited to participate, 57 individuals responded to the survey. However, due to attrition during the survey process, portions of the survey (demographic data) were only completed by 42 participants. Most participants owned their homes (40, 95.24%) while only two (4.76%) rented. The participants' tenure in Tucson was largely bimodal, with 13 respondents (30.95%) having lived in Tucson for less than five years, 19 (45.24%) having lived in the city of Tucson for 16 years or more, and the remaining respondents having lived there for 5-15 years. The average household income of respondents was well above the Tucson median with 27 (72.98%) reporting an income over $50,000 and 40.54% reporting an income over $50,000 (the 2015 median household income in the Tucson Metropolitan Statistical Area (MSA) was $37,149) (United States Census Bureau, 2017). Additionally, the educational level of respondents was disproportionately high with 18 (42.86%) holding a Masters, Professional or Doctorate degree and 12 (28.57%) holding a bachelor's degree compared to the average educational levels in Tucson, AZ where an estimated 27.5% of people aged 25 or more held bachelor's degrees or higher from 2011-2015 (U.S Census Bureau, 2017).

TABLE 6. Demographic Characteristics.

Variables	Levels	Frequency (Total = 42)	Percentage (Total = 100%)
Age	19- under	2	4.8
	20-24	1	2.4
	25-34	3	7.1
	35-44-	11	26.2
	45-54	7	16.7
	55+	18	42.9
Gender	Male	22	52.4
	Female	19	45.2
	No Response	1	2.4
Educational Level	Some high school	2	4.8
	High school or GED equivalent	3	7.1
	Some college credit	7	16.7
	Bachelors degree	12	28.6
	Masters, professional, or doctorate degree	18	42.9
Time Lived in Tucson	<5 years	13	31.
	5-10 years	6	14.3
	11-15 years	4	9.5
	16+ years	19	45.2
Household Income	$25,000-$34,999	4	10.8
	$35,000-$49,999	6	16.2
	$50,000-$74,999	6	16.2
	$75,000-$99,999	6	16.2
	$100,000 +	15	40.5
Home Ownership	Yes	40	95.2
	No	2	4.8

Number of adults in household	1	6	14.6
	2	29	70.7
	3+	6	14.6
Number of children in household	0	33	78.6
	1	5	11.9
	2	3	7.1
	3	1	2.4

TABLE 7. Survey Demographics Compared with Tucson AZ Demographics.

Variables	**Survey Average (Total population =42)**			**Tucson Census Median (Total population= 530,706 -July 1, 2016)**	
Age	45 – 54			36	
Gender	45.23% Female	52.38% Male	2% No Answer	51.10% Female	48.90% Male
Bachelors, Masters, Professional, or Doctorate degree	71.42%			25.80%	
Average Household Income	$75,000-$99,999			$47,560	
Average Adult Household Size	2			2.42	
Single-Family Owner-Occupied Home	73.7%			48.7%	

As can be seen by comparing survey demographics to Tucson's demographics at large, the survey respondents are significantly more educated, wealthy, and older than the average Tucson resident. In some respects, this is not surprising, given that all of the homes surveyed were recently built and are single family homes. According to data collected from the National Association of Realtors, Tucson MSA's 2015 median sales price of $182,900 (20.2% below the national median) (MAP, 2017) and only 3.7% of Tucson's population lives in single family homes (Census Bureau, 2017), therefore some demographic differences in the sample population is not surprising.

RQ1: ***Based on stakeholder interviews, what are the multi-level user-experience barriers to reusing residential graywater in homes built after the RGWO?***

The following results from Study 1 discuss the importance of end user experience in residential water reuse and the barriers to reusing residential graywater. Twelve themes that were coded from qualitative data in Study 1 are presented and analyzed below within the structure of an ecological model (Bronfenbrenner & Evans, 2000), with the addition of survey data to better illustrate how social barriers interact at multiple scales.

Policy Level Barriers.

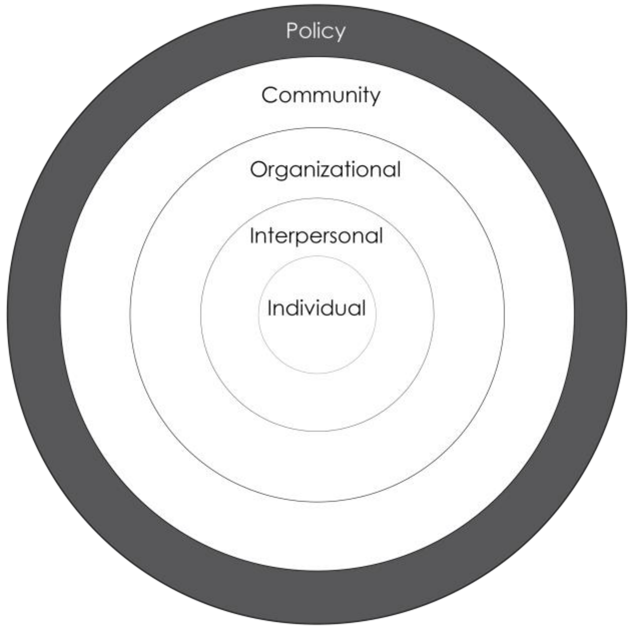


Figure 10. Ecological Model (Policy). Author’s interpretation of McLeroy et al. (1988).

Non-Integrated Policy Creation. At the time the RGWO was passed, the social and political climate were receptive to graywater usage, and residential graywater was presented as a platform for extending Tucson’s water conservation efforts. Before implementing the policy, a group of stakeholders (called Tucson's Graywater and Rainwater Stakeholder Group) was assembled to provide critical feedback on the project. While the policy represented a monumental step forward in acknowledging the potential benefit of residential graywater use, stakeholders voiced concern that lack of specificity in the wording of the ordinance allowed for a flexible interpretation that often benefited the builder rather than the homeowner. Because design specifications were flexible and vague to accommodate a variety of building types, some of the stakeholders believed the ordinance was not implemented in a way that benefited the homeowner.

Some graywater activists noted that graywater stub outs were placed in locations that were often inaccessible or unnoticed by homeowners (for example, on the side of the house opposite from the yard), thereby deflating the potential impact of the ordinance. In 2012, revisions were made to the ordinance to both encourage the specific use of gravity fed systems, but to also stipulate enforcement of the ordinance. One water conservation educator noted that design barriers were not simply due to negligence on the part of builders, but to the lack of specificity in the ordinance wording, misplaced incentive mechanisms (discussed later), and a lack of educational outreach to the organizations responsible for implementing the ordinance:

> Some of the issues that emerged were from plumbers and engineers. Many had/have no direct experience with graywater systems and they are relying on outdated information to determine how to install these systems. Many of them turn towards expensive pumps and containers, in part because these are the companies spending the most money on advertising, so that's what they see and that is what they think graywater needs to look like (Water Conservation Educator, Participant 2)

Planning. Planning for the implications of the policy at the regional scale emerged as a controversial element that appeared to hinder the integration of the ordinance. Tucson Water has been producing and delivering reclaimed water since 1984. It is one of the first water utilities in the nation to begin recycling water, treating it for irrigation and other non-drinking water use (City of Tucson, 2016). One stakeholder explained:

> There has been controversy over whether or not residential graywater reuse at a large scale is a good idea or not. The city reclaims waste water already, and that may be a more effective effort at water reclamation instead of having individuals reusing their graywater (Water Conservation Researcher, Participant 7).

Currently there are more than 1,000 sites using Tucson's reclaimed water for irrigation and landscaping, including: 50 parks, 65 schools, more than 700 single-family homes and 18 golf courses (Tucson, 2016). Large Scale residential graywater use would deflate the potential for a city-run water reclamation program for residential use. Some of the stakeholder interviews suggested that there was a disconnect between the city's pre-established conservation foci and the RGWO, as seen in the quotes above.

Community Level Barriers.

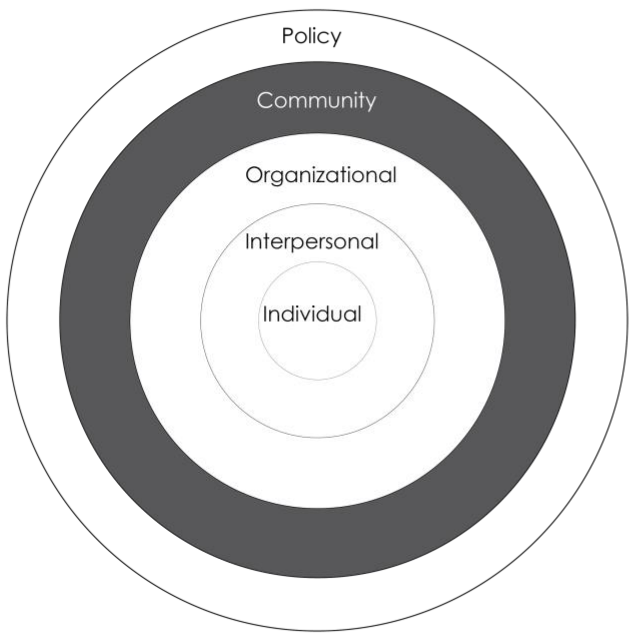


Figure 11. Ecological Model (Community)

Author's interpretation of McLeroy et al. (1988).

Collective Action. The theme of collective action at the neighborhood scale emerged from the interviews as an overlooked aspect of the RGWO implementation. Tucson has fostered a citywide culture around water conservation; participants highlighted the latent potential for communities to work together at the grassroots level to improve their neighborhoods through graywater and rainwater harvesting if communities were orchestrated to do so. One of the builders participating in the study acknowledged that one of the largest issues encountered was a lack of planning as to how to effectively utilize the graywater once a system was installed. Integrating both large neighborhood scale planning (contouring, lot size planning, the potential of sharing irrigation systems) and home site planning into the process of designing residential graywater systems. Directing multiple graywater systems to a shared feature (a park, for example) could have a much more powerful outcome for neighborhoods, but, “there is no overarching organization that will make this happen” (Participant 3). There is potential for individuals to work together to collectively grow shared vegetation or shading trees:

> For example, an HOA could easily do this. It’s very feasible if people just band together. They could set up graywater and rainwater systems to collectively grow fruit trees or other shading plants, but right now the burden is on the homeowner to do all of this themselves (Residential Builder, Participant 3).

Homeowners may want to implement their own graywater systems but not have the ability to do so at a collective scale:

> Yes, graywater is an underutilized resource, yes we need to start using it, but we need people on board for it to work. We need to plan how to utilize the water. For a while there was this graywater craze here, people got really into it, but there wasn’t enough time spent thinking about how the water would be used or what they might do if they encountered problems. That’s why I think it really needs to be thought out better. We could all use more water on our properties (Residential Builder, Participant 3).

The interviews highlight the importance of planning CAPS to operate at multiple scales, with thought given to the end results of the policy (in this case, how and where water will be reused).

Organizational Level Barriers

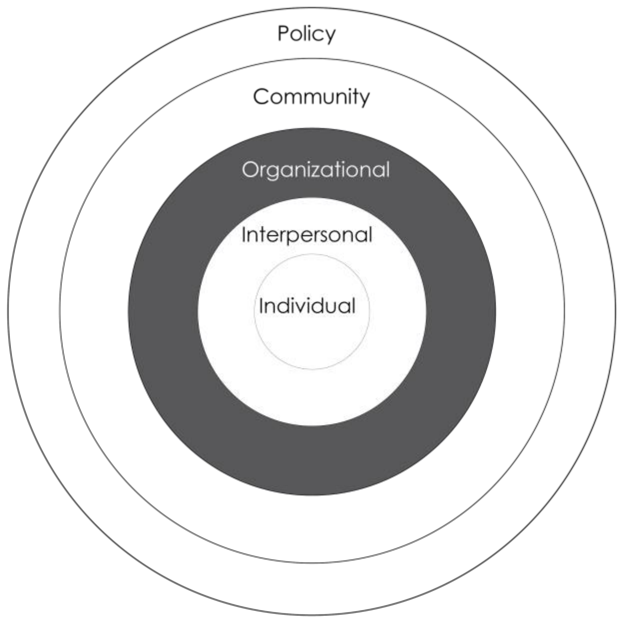


Figure 12. Ecological Model (Organizational)

Author's interpretation of McLeroy et al. (1988).

Feedback Loops. Graywater activists and researchers expressed frustration at the lack of available knowledge on the repercussions of the RGWO. Although newly built homes were inspected for compliance to the ordinance, research efforts were not made to determine how or if homeowners understood or used their dually plumbed homes for graywater reuse. Builders and graywater activists cited the lack of information as one of the barriers to revising the ordinance to mandate more specific design parameters:

> I'd like to know whether people are aware that their homes are plumbed for graywater use. If they don't know what a stub out is, I'd like to know what they thought it was and

> where it was. What do they think graywater harvesting is? What problems have they had? How do they deal with maintenance? (Water Conservation Activist, Participant 8).

There appeared to be a disconnect between what some builders and activists expected and the city's expectations for the ordinance.

> There really is a need to review how and if graywater systems are being used, because we're not seeing what's installed, there's no feedback from the homeowner. The city didn't set up that feedback loop. I'm not really sure why (Water Conservation Educator, Participant 2).

Incentives. The City of Tucson's Water Rebate Program offers rebates up to $1,000 and graywater workshops when a permanent graywater irrigation system is installed in a home residence. However only 104 of the rebates had been used by August 2016 although 773 people attended the workshops (D. Ransom, personal communication, August 11, 2016). Participants speculated that the rebates were not as well utilized because the rebate process was time consuming and because rerouting water from washing machines (laundry to landscape) was relatively inexpensive and easy to do without financial aid. Interview participants emphasized that architects, builders and developers were overlooked in the incentivizing process, although their actions determine the ease of use for the homeowner.

> There are not enough incentives for installing graywater systems, and in new construction, builders were not incentivized to put in graywater systems, even though doing so provides easy access to graywater use in the future (Architect and Educator, Participant 6).

The use of incentives can be a powerful motivator if directed towards stakeholders with the most leverage in implementing the policy at hand.

Habitual Routine. Graywater educators suggested that residential graywater use is limited by the habits and routines of individuals and organizations avoidant of new or risky techniques.

Practitioners of many fields retain the methods and techniques introduced during their education. Resistance to changing techniques may be due to fear of liability, but also to a lack of educational opportunities.

> I'm not sure why they [plumbers, architects, builders] are so resistant to graywater, it might be a fear of failure, it might be because they're looking at old materials. The ordinance really needs to push gravity fed systems; they're the simplest, the cheapest, and require the least amount of maintenance (Water Conservation Educator, Participant 2).

Architects and builders also expressed frustration at misunderstandings expounded by some graywater activists, explaining that the technical reasons graywater was difficult to design for gravity fed graywater systems was not only restricted to habit and routine but to larger restrictions based on codes and standardized building practices.

Interpersonal Level Barriers.

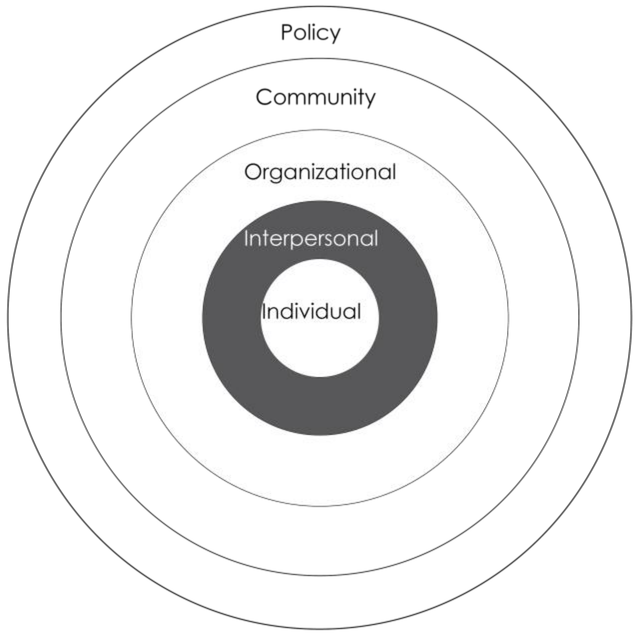


Figure 13. Ecological Model (Interpersonal)

Author's interpretation of McLeroy et al. (1988).

Education. It became evident that a service gap existed for installing and troubleshooting graywater systems. One graywater user recalled his failed attempt to install a valve to easily divert graywater from his washing machine due to an inability to find a plumber who knew how to do the work. Two others discussed their confusion over how personal care products can harm plants. When asked why they did not reuse graywater, one survey participant noted that their plumber had been reluctant to integrate a graywater stub-out into plumbing system. Graywater educators advocated for educational workshops for designers, plumbers and contractors, not just homeowners:

> There's also a need to help people trouble shoot their problems. Right now there isn't an easy way for people to get help with their graywater systems. If I were a homeowner who didn't know how to work a graywater system, I don't think I'd know who to call for help. There's a personal gap; there aren't enough people who know how to work and install graywater systems (Environmental Consultant (and Graywater User), Participant 4).

Individual Level Barriers

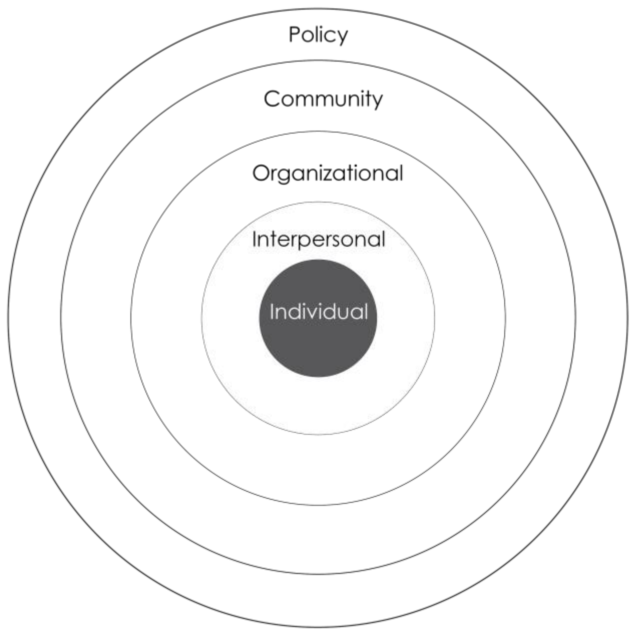


Figure 14. Ecological Model (Individual).

Author's interpretation of McLeroy et al. (1988).

No perceived need. Some do not perceive water reuse to be a necessity in their residential environment, either because of existing sprinkler systems, or because of low water demand landscapes. While graywater was most frequently used on shrubs or bushes (20.83%)

and shade or ornamental trees (12.05%), most participants (48, 78.35%) reported Xeriscaping around their homes, which may reduce the real and perceived need for outdoor water reuse.

Awareness. Many stakeholders expressed doubt over whether or not new homeowners were made aware that reusing water from their homes was a possibility, or that their homes were plumbed for graywater use. Graywater educators and researchers were unaware of any effort on the part of the city or developers to inform homeowners of the potential for graywater reuse. Many also hypothesized that if residents became aware of their home's potential for graywater use, it was through efforts of the community or larger water conservation efforts expounded by Tucson. Because the ordinance only impacts residential development built after 2010, some stakeholders expressed concern over different values of long term residents (who tend to live in older homes) compared to incoming residents.

Inconvenience. One of the largest barriers to residential graywater use is the inconvenience of installation of graywater irrigation systems. Because the RGWO does not require that graywater irrigation systems be installed with new homes, only that the homes be built to facilitate graywater use at a later date, effort from the homeowner is required even to install the most basic laundry-to-landscape gravity fed irrigation systems. As one builder noted:

> Even if all houses were plumbed and set up with a graywater system, I bet only 50% or so would use it. It's not a one-time investment, it's something you have to work on year after year. So graywater reuse is not a one-fix for everyone (Residential Builder, Participant 3).

As mentioned earlier, education, cost, and the limited availability of trained professionals can make gray water use a daunting task for many homeowners. For people wanting to utilize graywater from multiple parts of their home (showers, hand sinks, etc.) a pump is usually required to redistribute water to the landscape. Pumps can range in price but are generally much more expensive and maintenance intensive than simple gravity fed systems.

Education and Environmental Literacy. When planning how to best reuse residential water, homeowners must consider both local and regional environmental contexts. Soil types, site topography, and precipitation can alter the impacts of graywater use. One stakeholder emphasized the climatic variation occurring in the late summer season:

> Maintaining the systems can be a lot of work, because you know we have a monsoon season, pretty much the only season where we're getting a lot of water, and if you're using a catchment area, those areas can fill up with water and be breeding grounds for mosquitoes, but people continued to flush their graywater onto the landscape, so we need a better way of educating people about responding to situational changes (Residential Builder, Participant 3).

Safe residential graywater use requires careful attention and awareness to not only how systems are designed and used, but also to what personal care products (PCP's) are entered into the water stream (Daughton, C. G., 2003). For example, many soaps contain salts that can harm plant life with extended use. One graywater user explained:

> Another issue is all the things you have to think about when you wash your clothes. For example, when you buy new clothes, you shouldn't wash them for the first time and send the water out to the yard because there are all sorts of harmful dyes and insecticides (Graywater Activist and Graywater User, Participant 1).

Some advocates claim that understanding how PCP's impact plant growth and soil quality is not only good for graywater systems, but for the watershed at large. However, substantial educational and behavioral barriers make graywater use a challenge for many would be users.

> Education is the biggest problem, and you know, it's not for everyone. Some people are really busy, some people don't want to have fruit trees in their yard, some people don't want to do the maintenance. It's not for everyone (Residential Builder, Participant 3).

As one participant pointed out, “Ultimately it comes down to the property owner to incorporate graywater into their daily routine.” (Water Conservation Consultant, Participant 4).

Aesthetics. Unless carefully designed, graywater systems may not meet the aesthetic standards of some homeowners. Because most graywater research has revolved around safety and feasibility, the aesthetics (both indoors and outdoors) can be overlooked. As one participant (3) noted:

> These systems aren’t always beautiful. Maybe I’m too comfortable with a rough aesthetic. I realize not everyone is comfortable with that.

For stakeholders who are comfortable with designs catering to the pragmatic, it can be difficult to recognize aesthetics as a barrier for new homeowners. As one graywater user stated:

> I think that it’s important to design things that are elegant and attractive to use. Everything should be designed to be attractive. Some of the activists don’t get that, they’re more concerned with practicality and making things work. They have a different sense of aesthetics (Graywater Activist (and Graywater User), Participant 1).

He went on to explain that aesthetic concerns extend from inside the home, to the yard, and to the wider neighborhood.

> People also want to fit in. If graywater is really going to take off, these systems need to be designed to ‘fit into the neighborhood aesthetic’ (Graywater Activist (and Graywater User), Participant 1).

Currently, aesthetics remain a barrier in need of more recognition from graywater system designers at all scales.

RQ 2: Did the 2010 RGWO encourage residential graywater recycling in Tucson, Arizona?

Results indicate that the RGWO did not facilitate widespread graywater reuse for the majority of home owners, although there was a modest impact. Most survey respondents (51, 89.47%) reported that they did not reuse graywater from their homes. Only six of the participants currently (4) or previously (2) reused graywater from their home. Extrapolating these numbers to the number of homes built after the ordinance, only 10.5% are likely reusing or have reused graywater (roughly 254 of 2,422)[5].

As a CAP, the RGWO did not seem to enable widespread potable water conservation. Previous research has estimated that in 2009, roughly 20,000-30,000 households (50,000-80,000 people) that may have been using gray water systems before the RGWO was put into effect (Rock, 2009). Extrapolating to Tucson's current population, that means 9.42%- 15.07% of the total population might be using graywater, with or without having their home plumbed more effectively for graywater use. Although these numbers are open to conjecture, and are only estimates, they prompt a deeper line of questioning as to whether or not the 10.5% of graywater users in the survey are simply representative of larger water reuse habits that have been in existence for many years, or whether the RGWO facilitated graywater reuse at a marginal scale.

[5] The results of this study cannot definitively claim that the RGWO was responsible for the graywater use, only that select respondents claim to reuse water.

TABLE 8. Reported number of graywater users.

Answers	Number	Percentage
Yes	4	7.02%
Yes, in the past but not now. *	2	3.51%
No	51	89.47%
Total	57	100%

** Reported reasons for not using graywater now included home relocation and the work of having to hand collect graywater from a washing machine.*

Despite not being active graywater users, the majority (63.16%, 36) of participants knew that it is legal to reuse graywater from their homes if following the best practices defined by the state of Arizona (Yes: 36, 63.16%, No: 21, 36.84%), as shown in Table 9.

TABLE 9. Participants who knew graywater use is legal in Arizona.

Answers	Frequency	Percentage
Yes	36	63.26%
No	21	36.84%

n=57

As summarized in Table 10, the majority of participants (44, 77.19%) said they had heard of graywater before receiving the survey, although only eight (14.04%) had heard about the RGWO (two of whom are current graywater users).

TABLE 10. Participants who had heard about graywater pre-survey.

Answers	Frequency	Percentage
Yes	44	77.19%
No	13	22.81%

n=57

TABLE 11. Participants who had heard about the RGWO pre-survey.

Answers	Frequency	Percentage
Yes	8	14.04%
No	49	85.96%

n=57

Although most of the homes surveyed should have had a ‘stub-out’ on the outside of the home to facilitate graywater reuse, the majority of participants (39, 68.42%) had never heard of a stub-out pipe before the survey. When asked whether or not their homes had a stub-out pipe on the outside of their house, 27 (47.37%) of respondents were unsure, 9 (15.79%) said yes, and 21 (36.84%) said no (Table 12).

TABLE 12. Self-reported knowledge of stub-out installment on home.

Answers	Frequency	Percentage
Yes	9	15.79%
No	21	36.84%
Unsure	27	47.37%

n=57

Of the few (n=6) participants who did report using graywater from their homes, the majority (75%) reported that they used it almost every day, although one person (25%) reported using it hardly ever, (two others did not indicate frequency of use) (Table 13). Note that due to the low number of respondents reporting to use graywater uses are reported but cannot be extrapolated to the general population.

TABLE 13. Frequency of graywater use.

Answers	Number	Percentage
Almost every day	3	75%
Once a week	0	0%
Once a month	0	0%
Hardly ever	1	25%

n=6

**Respondents were also asked to distinguish between graywater use in the summer vs. the winter seasons, but responses were static across season. Two participants did not answer this question because they had been graywater users but currently were not.*

As reported in Table 16, the most common uses for graywater were for watering shrubs or bushes (20.83%) and shade or ornamental trees (12.05%). Three participants collected graywater through the plumbing in their house, while only one used a direct laundry-to-landscape method as described in Table 14. Most graywater was reportedly reused through plumbing systems rather than by hand; the washing machine was the most frequently used source of graywater, although bathtubs and hand sinks were used as well (Table 13). In conclusion, although a few respondents were graywater users, most residents were unaware that their houses were designed to facilitate water reuse and were not active graywater users.

TABLE 14. Sources of graywater used.

Answers	Number	Percentage
Washing machine	4	40.00%
Bathtub or shower	3	33.33%
Hand sinks	3	33.33%
Kitchen sink	0	0%

n=6

TABLE 15. Description of graywater systems.

Answers	Number	Percentage
Hand collection: Using buckets or containers to save graywater temporarily	0	0.00%
Plumbing: Graywater collected through piping installed in my house	3	75.00%
Laundry to Landscape: Washing machine connection to irrigation system or pump	1	25.00%

n=6

The few participants who did reuse water reported using it most frequently to water trees, bushes, and potted plants rather than for indoor uses like toilet flushing (Table 15).

TABLE 16. Locations of graywater use.

Answers	Number	Percentage
Shade/Ornamental Trees	3	12.05%
Fruit/Nut trees	2	8.33%
Wildflowers / Perennials	1	4.17%

Shrub / Rose Bushes	5	20.83%
Potted Plants	3	12.05%
Vegetable / Herb garden	0	0.00%
Compost	0	0.00%
Toilet flushing	1	4.17%
Car washing	0	0.00%

n=6

RQ 3: Are there individual-level predictors of graywater reuse practices?

Cluster Groupings

When asked how interested they were in reusing water from their homes, 26 (45.64%) participants were very or extremely interested, 21 (36.8%) were moderately/slightly interested, and 10 (17.5%) were only slightly or not at all interested, as summarized in Tables 16 and 17

TABLE 17. Interest in reusing graywater; cross-tabulated with graywater use.

Interest in graywater	Participants graywater use			
	No	**Yes**	**Yes in the past but not now**	**Total**
Extremely interested	11	4	0	15
Very interested	9	0	2	11
Moderately interested	13	0	0	13
Slightly interested	8	0	0	8

Not interested at all	10	0	0	10
Total	51	4	2	57

TABLE 18. Interest in reusing graywater.

Answers	Frequency	Percentage
Extremely/Very interested	26	45.64%
Moderately/Slightly interested	21	36.8%
Not interested at all	10	17.5%
Total	57	100%

n=57

To better understand the characteristics of participants who were or were not interested and knowledgeable about graywater use, a cluster analysis was conducted. Using a two-step cluster analysis (SPSS, 2001), the respondents were split into two primary clusters based on their knowledge of and interest in graywater reuse. Five input variables were entered to create 2 cluster groupings from the 57 participants (see Table 18).

TABLE 19. Cluster Analysis Variables.

Cluster use	Variables
Outcome variables used to determine cluster	1. Graywater Use 2. Graywater Awareness • 2.a Knowledge of graywater • 2.b Knowledge of stub-out • 2.c Legal use of graywater in AZ 3. Graywater Interest
Demographic variables cross tabulated	1. Age

with cluster groups	2. Home ownership 3. Time lived in Tucson 4. Household income 5. Educational background 6. Gender

Cluster 1 is referred to as "Graywater Aware" and Cluster 2 is termed "Graywater Unaware". The results of the cluster analysis allow us to better understand which target demographics are receiving information, and therefore, which demographics may need to be better targeted for future educational outreach.

Cluster 1: Graywater Aware Group (n=36, 63.2%, Bayesian information criterion (BIC) (466.816)

The Graywater Aware group tended to be highly educated (with advanced degrees), over age 55 predominately male, wealthy, and had either recently moved (>5 years) or had lived in Tucson over 16 years.

Cluster 2: Graywater Unaware (n=21, 36.8%, Bayesian information criterion BIC (398.611)

The Graywater Unaware group tended to hold a bachelor's degree or higher, be under age 55, predominately female, with a normal wealth distribution and a normal distribution of time lived in Tucson (See Figures 15-18).

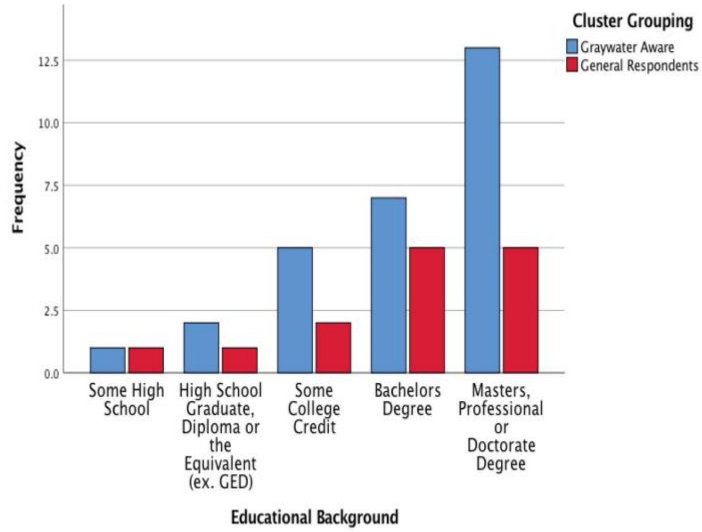


Figure 15. Cluster Groupings Educational Background.

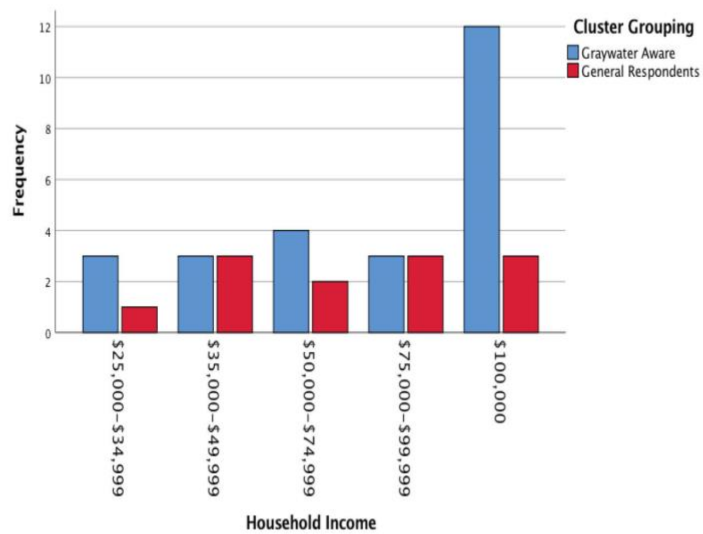


Figure 16. Cluster Groupings Household Income

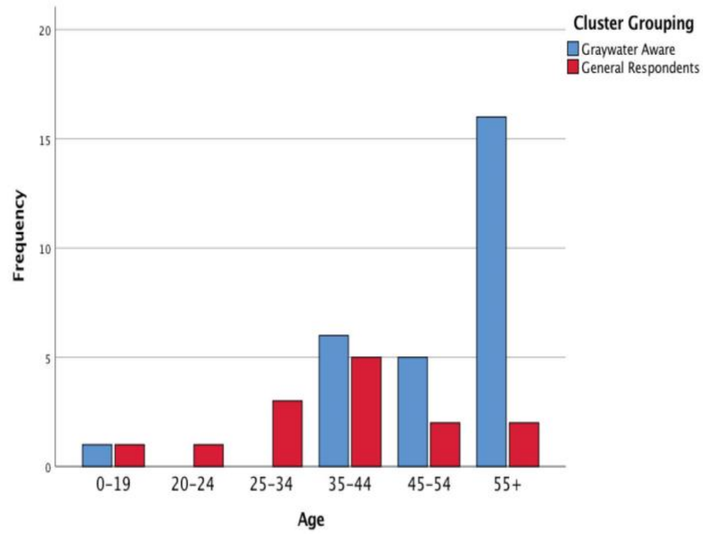


Figure 17. Cluster Groupings Age Group

All of the Graywater Aware group (36) but none of the Graywater Unaware group (21) knew that it is legal to reuse graywater in the state of AZ (Figure 18).

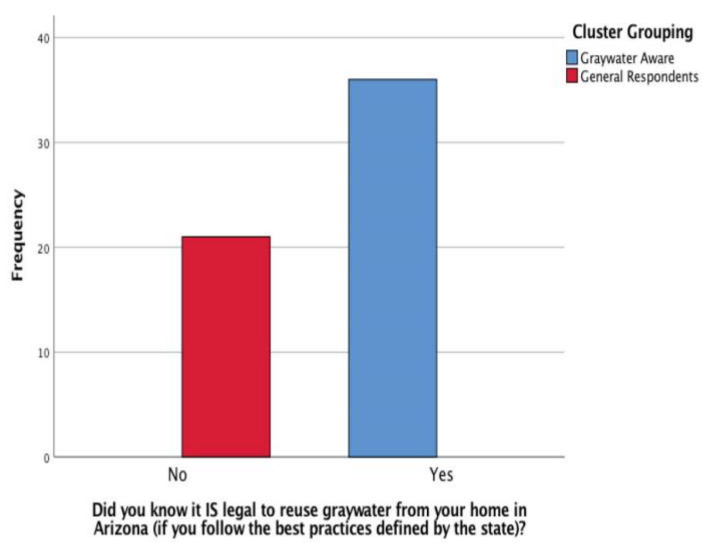


Figure 18. Cluster Groupings Awareness of Graywater Legality

Only 8 in Graywater Aware had heard of the RGWO (Figure 19), whereas none of the Graywater Unaware had heard about the policy.

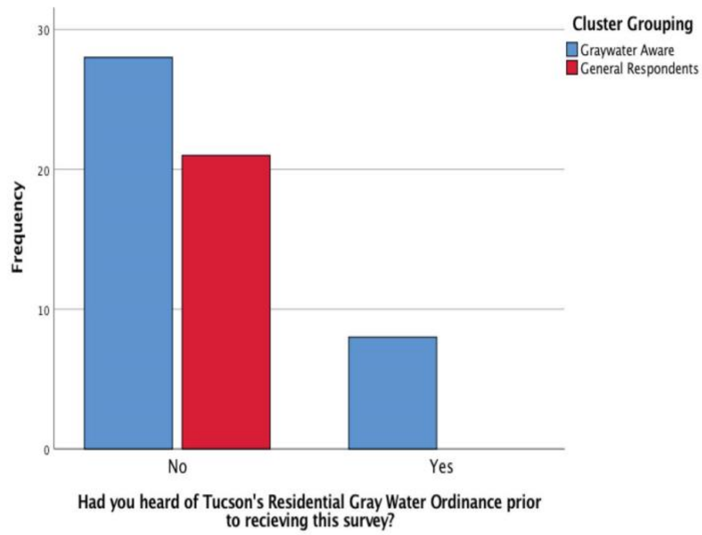


Figure 19. Cluster Groupings Awareness of Gray Water Ordinance

Only 15 of the Graywater Aware group knew what a 'stub-out' was, compared to 3 in the Graywater Unaware. Of the Graywater Aware, 24 were moderately to extremely interested in reusing graywater, compared to 15 of Graywater Unaware. A one-way ANOVA was run to assess whether or not the two clusters demonstrated a difference in their perceived Water Conservation Norms or in perceived Water Conservation Efficacy, but results were not statistically significant.

TABLE 20. Two Step Cluster Analysis Results

Graywater Knowledge Input Variables	Cluster 1 Graywater Knowledgeable (n=36)				Cluster 2 Graywater Unaware (n=21)			
	Yes		No		Yes		No	
	#	%	#	%	#	%	#	%
Had heard of graywater prior to receiving the survey.	33	76.9%	3	23.1%	11	25.0%	10	76.9%
Knew it IS legal to reuse graywater in the state of Arizona	36	100.0%	0	0.0%	0	0.0%	21	100.0%
Had heard of Tucson's RGWO before receiving the survey.	8	100.0%	28	57.1%	0	0.0%	21	100.0%
Had heard of stub-outs prior to receiving the survey.	15	83.3%	21	53.8%	3	16.7%	18	46.2%
Interested in reusing graywater.	28	77.78%	8	22.22%	19	90.47%	2	9.52%

Demographic Variables	Levels	Cluster 1 Graywater Knowledgeable (n=36)		Cluster 2 Graywater Unaware (n=21)	
		#	%	#	%
Age	-19	1	4.5%	0	0.0%
	20-24	0	0.0%	1	6.7%
	25-34	1	4.5%	2	13.3%
	35-44	6	27.3%	5	33.3%
	45-54	3	13.6%	4	26.7%
	55+	11	50.0%	3	20.0%
Gender	Male	19	67.9%	3	21.4%
	Female	9	32.1%	10	71.4%
	No Response	0	0.0%	1	7.1%
Education Level	Some high school	1	3.6%	1	7.1%

	High school graduate or GED equivalent	2	7.1%	1	7.1%
	Some college credit	5	17.9%	2	14.3%
	Bachelor’s Degree	7	25.0%	5	35.7%
	Masters, professional, or doctorate degree	13	46.4%	5	35.7%
Time Lived in Tucson	<5 years	10	35.7%	3	21.4%
	5-10 years	2	7.1%	4	28.6%
	11-15 years	2	7.1%	2	14.3%
	16+ years	14	50%	5	37.7%
Household Income	$25,000-$34,999	3	12.0%	1	8.3%
	$35,000-$49,999	3	12.0%	3	25.0%
	$50,000-$74,999	4	16.0%	2	16.7%
	$75,000-$99,999	3	12.0%	3	25.0%
	$100,000 +	12	48.0%	3	25.0%
Home Ownership	Rent	1	2%	1	4.76%
	Own	27	75%	13	61.90%

**Note: not all counts equate to the total n of each column due to attrition during some of the survey questions. The results that were measured are presented above.*

Binary Logistic Regression Analysis

To further examine the individual predictors of graywater use and awareness, a binomial logistic regression analysis was conducted with graywater use, graywater awareness, and graywater interest as the dichotomous dependent variable.

There were a total of 32 valid responses for each of the questions used in the regression models (participants providing incomplete data to the questions were removed from the dataset).

Logistic regression provides the odds of an event occurring based on specific input variables (demographics), therefore the odds ratios (OR) are reported below. The variables on which the regression was run included the following questions about graywater use and awareness:

TABLE 21. Binary Logistic Regression Variables.

Variables	
Explanatory Demographic Variables	1. Age 2. Home ownership 3. Time lived in Tucson 4. Household income 5. Educational background 6. Gender
Dependent Variables	1. Graywater Use 2. Graywater Awareness • 2.a Knowledge of graywater • 2.b Knowledge of stub-out • 2.c Legal use of graywater in AZ 3. Graywater Interest

1. *Graywater use*

None of the demographic variables were statistically significant in predicting whether or not participants actually reused graywater. The results obtained from the logistic regression analysis for graywater use must be interpreted with a degree of caution because of the extremely small sample size (6) to predictor (32) ratio. Given the low number of participants who claimed to reuse graywater (6), it is not surprising that no significance was found.

2. Graywater awareness

2.a Knowledge of graywater

A binomial logistic regression was run to understand the association of age, home ownership, time lived in Tucson, household income, educational background and gender on the whether or not people had heard of graywater prior to the survey. The goodness-of-fit tests are all greater than the significance level of 0.05, meaning there is not enough evidence to conclude that the model does not fit the data (Table 22).

Employing a .05 criterion of statistical significance gender ($p = .039$) statistically significantly predicted whether or not people had heard about graywater. The odds ratio for gender (85.58 OR) indicated that men (coded as 1) had significantly higher odds of having heard about graywater than did women. Time lived in Tucson was also statistically significant at a .10 criterion of statistical significance ($p = .090$). The OR indicate that for every increase of five years of living in Tucson, participants had six times the odds of having heard of graywater (6.190 OR).

TABLE 22. Knowledge of Graywater Logistic Binary Regression.

Variable	Coefficient	95% CI	P-Value	OR
Gender	-4.450	(-8.681, -0.218)	0.0393	85.58
Time Lived in Tucson	1.823	(-0.288, 3.934)	0.0906	6.190
Goodness of Fit Test			**P-Value**	
Deviance			0.967	
Pearson			0.9554	
Hosmer-Lemeshow			0.8069	
Regression Equation	Y' = −10.96 + 0.5487 Age + 5.80 Home Ownership + 1.823 Time Lived in Tucson AZ + 0.3589 Household Income + 1.613 Educational Background − 4.450 Gender			

2.b Knowledge of stub-outs

There were no significant effects of age, home ownership, time lived in Tucson, household income, educational background or gender on the whether or not people had heard of stub-outs prior to the survey in a binomial logistic regression[6].

2.c Legal use of graywater in Arizona

The influence of age, home ownership, time lived in Tucson, household income, educational background and gender was tested through binomial regression on whether or not people knew it *is* legal to reuse graywater in AZ. Both gender (p = .0184) and age (p = .0147)

[6] Knowledge of stub-outs was recoded as a binary variable to remove uncertain answers from the data set (1=yes, 0=no, 0=not sure).

were statistically significant predictors of whether or not people knew it is legal to reuse graywater in Arizona, but none of the other variables were significant (Table 22). For every increase of 10 years in age, the odds of knowing about the legality of water reuse in AZ increased by roughly a factor of four (3.868 OR). Male participants' odds of knowing about AZ graywater legality were increased by a factor of almost 20 (19.551 OR) compared to women. The deviance and Hosmer-Lemeshow goodness-of-fit tests are greater than the significance level of 0.05, meaning there is not enough evidence to conclude that the model does not fit the data, although the Pearson test reported a significance level of 0.000.

TABLE 23. Legal Use of Graywater Logistic Binary Regression.

Variable	Coefficient	95% CI	P-Value	OR
Age	1.3527	(0.2655, 2.4400)	0.0147	3.868
Gender	2.973	(0.500, 5.446)	0.0184	19.551
Goodness of Fit Test			**P-Value**	
Deviance			0.7345	
Pearson			0.0008	
Hosmer-Lemeshow			0.0617	
Regression Equation	Y' = −8.403 + 1.3527 Age + 0.794 Home Ownership + 0.6630 Time Lived in Tucson AZ + 0.3154 Household Income − 0.5512 Educational Background + 2.973 Gender			

3. Graywater interest

No demographic variables were statistically significant in predicting whether or not participants were interested in reusing water, were actually reusing graywater, or knew whether or not their home had a stub-out for graywater.

Conservation and Efficacy Likert Scales

Water conservation norms and conservation efficacy. The scale means indicate that most people felt water conservation was a norm amongst friends, peers and people important to them, although perhaps not a strong norm (x=2.25, "somewhat agree"). The means on the perceived efficacy scale were also low, indicating that participants felt enabled to participate in water conservation (x=1.79, "somewhat agree").

TABLE 24. Perceived Water Conservation Norms Scale
(1=strongly agree, 5=strongly disagree)

	Mean (sd)
1. Most people who are important to me care about water conservation.	1.98 (.841)
2. Most people who are important to me try to conserve water resources.	2.10 (.759)
3. Most of my friends and peers engage in water conserving behaviors.	2.67 (1.03)
Total (n=42)	2.25

TABLE 25. Water Conservation Efficacy Scale
(1=strongly agree, 5=strongly disagree)

	Mean (sd)
1. I think that I myself can contribute to the improvement of water conservation in my city.	2.07 (.841)
2. I know there are a number of things that I myself can do in order to conserve water.	1.52 (.671)
3. I believe that together we can do something about water conservation.	1.62 (.661)
4. I am confident that together we can solve the water conservation issue in my city.	1.93 (.838)
Total (n=42)	1.79

CHAPTER 4

Discussion

The overarching goal of this research was to offer a stakeholder and user-experience perspective on climate-adaptive policies (CAPs) using the RGWO as a case example. When consulting a variety of stakeholders, numerous barriers to reusing water at the residential scale were identified. These insights can provide policy designers with a better idea of the 'pain points' experienced by end users so that iterations can be incorporated into the policy. The results of this research shed light on the role of user experience in climate-adaptive policy implementation; highlighting how other climate-adaptive policies may be designed to act as 'experimental nodes' by integrating behavioral feedback from end users to ultimately improve policy implementation from an adaptive management perspective.

More than 2,000 homes were built after Tucson's Residential Gray Water Ordinance was passed. This research is the first that the researcher knows of evaluating whether or not the RGWO facilitated graywater reuse as it was intended to, and what barriers residents (the policy's end users) faced in installing and using graywater systems. This discussion is organized under the three research questions, followed by research limitations and future research explorations.

Research Question 1: What are the multi-level user-experience barriers to reusing residential graywater in homes designed to enable water reuse.

Various user-experience barriers to reusing residential graywater were identified at the policy, community, organizational, interpersonal, and individual levels. To ensure smooth delivery of policy mandates, educational systems need to be in place to support the introduction of new techniques or new fields. Because designing for graywater systems is still relatively new, many architects, builders, landscape contractors and plumbers were not equipped with the information they needed to install or design for graywater. Nor are they necessarily trained to communicate with one another in such a way that integrates architectural and site design. Personal barriers to installing graywater systems also posed challenges.

Information-action gaps between the end user (the homeowner) and the RGWO. The action gap highlights the importance of considering the end user when evaluating the implementation and success of a policy. The top three reasons participants said they had not used graywater from their homes, were that: (1) participants did not know how to install a graywater system (33, 34.38%), (2) participants were not familiar with graywater (17, 17.71%), and graywater systems were (3) too expensive (11, 11.46%). Policies requiring the direct engagement of citizen behavior or the alteration of personal habits may do well to evaluate the barriers or 'pain points' in achieving the intended outcomes of the policy. For example, if not knowing how to install a graywater system is a primary pain point in the case of the RGWO, offering a graywater installation service as part of a home purchasing process could be one example of a way to improve the residents experience with and access to water reuse. Because the RGWO does not require that graywater irrigation systems be installed with new homes, only that the homes be built to facilitate graywater use at a later date, effort from the homeowner is required even to install the most basic laundry-to-landscape gravity fed irrigation systems.

Using incentives to engage stakeholders with the most leverage in implementing the policy at hand. Conducting workshops with stakeholders who will be involved in implementing the policy (not just the end users) could also shed light on a variety of problem areas before a policy is implemented. For example, this research revealed that plumbers and building contractors may struggle with feeling comfortable or justified in installing graywater systems, making it challenging for homeowners to find professional support when they want to install a graywater system. Offering certifications to or special training for installation professionals could be an alternative way to build regional confidence in reusing graywater at the residential scale.

Performance-based policies. Non-prescriptive but performance-based climate-adaptive state policies may have the potential to reduce liability concerns while encouraging creative policy adaptations to local issues, thereby enabling innovative regional and local solutions that may be relevant to other municipalities. Inconsistent plumbing codes and legislation have hindered the development of standardized technological approaches for promoting the reuse of graywater (Little, 2000). As of 2013, twenty states have legalized some form of graywater reuse, but Arizona has one of the most permissive graywater laws in the U.S. For this reason, Tucson's Residential Gray Water Ordinance was supported at the state level because Arizona allows low-risk and low volume residential graywater users to operate without a permit as long as guidelines are followed (Ludwig, 2006). This, in turn, made it easier for municipalities and smaller organizations to support policies like the RGWO because state legislation alleviated some liability concern. Local and regional municipalities need to be able to adaptively respond to climate sensitive issues through political action and enabling local adaptive policies at the state level can encourage cities to test out more context specific innovative climatic responses. Climate-adaptive policies may have more impact if they are planned to operate at the community scale. Engaging the potential of grassroots endeavors may amplify the acceptance and integration of the policy.

Incorporating adaptive management strategies for evaluating the success of climate-adaptive policies can enable better feedback and adjustment of the policy, making them more effective over the long term while also providing insight for other municipalities considering similar initiatives.

Research Question 2: Did the 2010 RGWO encourage residential graywater recycling in Tucson, Arizona?

This research implies that the 2010 RGWO was only modestly successful in facilitating residential water reuse and conserving potable water as the policy intended. Based on the survey responses, an estimated 10.5% of people living in homes built after the RGWO are likely reusing or have reused graywater (roughly 254 of 2,422), meaning that there are still significant barriers inhibiting homeowners from reusing water. It should be noted however that due this study's small sample size and possibly non-representative population, the results may not be representative (see limitations section below). There seems to be a disconnect between the number of people very to extremely interested in using graywater, and the number of people who understand what a stub out is designed for and are aware that their homes are intended to support graywater use. It is possible that either: (1). The ordinance is not being followed to the expected extent or, more likely, (2). people are completely unaware that their homes are designed with a stub out to enable potential water reuse.

Most survey participants knew that it was legal to reuse graywater from their homes in

Arizona, and about a thrid had heard of graywater before, but only eight had heard about the RGWO. Survey results revealed that residents were largely unaware that their homes are designed to facilitate water reuse, or how to install a graywater system using the features of their homes. Almost a third of participants did not know how to install a graywater system and most were not familiar with graywater.

Although the participants selected for the survey presumably live in homes built with a stub-out pipe (or have successfully petitioned out of participating in the ordinance), the majority of participants had never heard of a stub-out pipe before the survey, indicating a severe information lag between the creators of the ordinance and the home owners. These findings emphasize the importance of evaluating the experience of the 'end-user' when implementing CAPs.

Research Question 3: Are there individual-level predictors of graywater reuse practices?

The two-step cluster analysis of resident survey results indicate that further user experience research is needed in both policy design and outreach efforts. The knowledge about graywater policy in Arizona is reaching primarily older, wealthier, highly educated, males[7]. Although this study does not have an explanation for this result, it is possible that 'the typical' channels of communication being used to put out information (i.e. websites, newsletter, political events) may not be as effective at reaching the larger population. Further research would be required as to what marketing/educational tactics might reach more new homeowners. Other

[7] Note that survey respondents' demographics are likely not representative of all new homeowners (See limitations section)

cities trying to raise awareness about other CAP's requiring citizen engagement could consider conducting a similar survey to assess interest in and knowledge about said policy.

While no demographic variables were statistically significant in predicting whether or not participants actually reused graywater (due in part to the small number of graywater users), some demographic variable were significant in predicting graywater knowledge. Men had higher odds of hearing about graywater ($p=.039$,.58 OR) and knowing about graywater legality (19.551 OR) than did women. Understanding demographic correlates of knowledge or interest in the policy at hand can provide government officials with a deeper understanding of which demographics may be receptive to receiving more information, and which demographics are not receiving the information. As with RQ2, these findings are limited by the modest response rate and small sample.

Limitations

There were several limitations to this research. In the following text, relevant threats to various types validity (i.e., construct, internal, external, statistical) are discussed with respect to each of the studies.

Study 1 Limitations

Internal Validity. Limitations to internal validity can be defined as compromises in confidence that a relationship exists between the independent and dependent variables.

Sample size. A small sample of graywater experts does not provide a conclusive and holistic understanding of the policy or the problems encountered for all stakeholders involved. For more conclusive and detailed conclusions to be drawn, a larger number of predefined 'expert groups' would need to be interviewed. Additionally, spending extended time in person in the region with different stakeholders would have provided a more in-context understanding of the challenges and influences these stakeholder groups hold in relation to one another and would have provided the data necessary for a grounded theory approach. However, this was not possible within the time and economic limitations of this masters thesis.

Construct Validity. Construct vaility can be thought of the extent to which the research is able to measure what it claims to study.

Interview Accuracy. Although most interviews were recorded and accordingly transcribed, the interviewer did have to rely on hand written notes (due to technical difficulties) occasionally, although effort was made to maintain verbal accuracy in transcribing statements. Additionally, because the interviews included various professionals, the questions around graywater use and barriers to graywater use had to be adapted to their specific knowledge set.

Interviewer bias. Because the researcher both conducted the interviews and coded the data without the assistance of another researcher, the conclusions drawn are necessarily a joint result of both the interviewers and the interviewee. As Joseph Maxwell points out in his book Qualitative Research Design: an interactive approach, in qualitative research, the researchers personal thought process cannot be removed from the conclusions drawn (Maxwell, 1996, p. 91), although some may argue that the closeness of the researcher to the data is what in part gives validity to the conclusions drawn. Acknowledging the limitations of both the study and the conclusions drawn does not necessarily deflate the value of the information garnered from the interviews however.

External Validity. External validity can be described as how well the data and conclusions from the data can be applied to other settings or populations.

Setting. The experiences of the select interviewees may not generalize to other individuals in similar positions but in different circumstances, and therefore a similar policy in another region could not be expected to face the same challenges revealed by interviewing Tucson's graywater stakeholders.

Study 2 Limitations

Internal Validity.

Little to no claim of causality can be made between the defined explanatory and outcome variables in the survey. All variables reported can only be considered correlational since none of the variables were actively manipulated by the researcher.

Research Design and Extraneous Variables. Because of the complexity of the topic, there may be various extraneous variables that could compete with the explanatory variables in explaining participants' graywater use (for example, this research was not able to deeply understand the specific environmental barriers that individuals may face in operating a graywater system like location of the stub-out, concerns over safety, time allowances for installing graywater systems, etc.). Although this research was able to determine that the RGWO did not facilitate widespread water reuse, no specific measures were made to determine a quantifiable amount of potable water conserved by the policy. Additionally, this research did not represent a true experiment with an active intervention, therefore making causal claims is not possible.

Attrition. The relatively small sample size of 57, reduced to 42 in some portions of the survey due technological challenges experienced early on in the study, presenting a challenge for statistical analysis. A larger participant pool from the original invitees would have provided more accurate data, however funds were not available to reach out to potential participants a second time.

Selection. Responding participants were not an accurate representation of the Tucson population in general. Only people living in homes built after the RGWO was passed were invited to participate in this research, however, participants had to self-select into the research.

External Validity

Setting. Because this research is largely a case study around one policy, the findings from this research are not generalizable to other cities or their specific policies, however insights can still be useful for other cities hoping to institute similar CAPs in the future by identifying potential barrier levels for policy implementation.

Selection. It is difficult to say to what extent the participants are representative of the initial population invited to participate in the survey since that data is not available to the researcher. Additionally, the fact that participants were invited via postcard and requested to take the survey online may have severely influenced the number and type of people choosing to participate in this research.

Construct Validity

The two likert scales, perceived water conservation norms (3-item, likert scale) and water conservation efficacy (4-item likert scale), were adapted from existing scales to better fit this context. The content validity of these measures may be weak due to the small number of items used to gather feedback and the fact that slight alterations were made in the scales. Long scales were avoided in this study to reduce respondent burden and user attrition. While the original (and adapted) scales were tested for reliability (cronbach alpha), validity was not reported.

Statistical Validity.

The small sample size of the survey population was exacerbated by attrition, making the sample size and consistency of data a threat to statistical validity. The small sample size and varied data input (nominal and ordinal) limited the types of statistical analyses that could be run and presented a threat to statistical validity.

Future Research

This research attempted to identify: a). whether or not the RGWO was successful in facilitating graywater use and b). barriers to both installing and using residential graywater. However, it was limited in its ability to interact with individual home-owners; no research was conducted on the step-by-step patterns of behavior involved in using individual residential graywater systems, and no research was conducted as to how much water participants using graywater systems were actually saving. Future research into the RGWO could use a pre-post study measuring household water consumption and use, with the installation of a graywater system acting as the design intervention (independent variable). Future research could also focus on the series of steps new homeowners must now go through to install a graywater system, to identify specific behavioral pain points and design to alleviate them, ideally monitoring the water saving repercussions of any interventions.

Conclusion

The system challenges induced by climate change (not to mention numerous other variables) have emphasized the need for more innovative resource management and flexible policy design. However, to create adaptive and useful policies, leaders must prioritize rapid innovation and iterative feedback into their climate-adaptive policy solutions. By taking a user-experience approach to both design interventions and subsequent policy design, cities may be better able to improve the results of the policy over time. CAPs that take in active feedback and go through iterative cycles may eventually be seen as a form of urban innovation rather than status-quo policies, much as the Living Laboratories movement considers the ecological or technical experiments embedded into cities (Evans, 2011; Evans & Karvonen, 2011).

Considering the roles specific stakeholders will play in policy implementation is paramount to understanding how the policy might ‘look on the ground’ as it’s disseminated through specific actors and end users. As discussed previously, cities striving to identify localized ‘transition pathways’ consisting in part of adaptive policies could benefit from seeing iterative feedback after an experimental node (in this case, the RGWO) has been implemented.

APPENDIX I

RECRUITMENT MATERIALS

Interview Recruitment Emails

Dear XXX,

I am a graduate student at Cornell University conducting research on the use of residential grey water recycling systems in Tucson, AZ. The purpose of my study is evaluating to what extent the 2010 Residential Gray Water Ordinance has facilitated grey water reuse, and what the current barriers are to recycling grey water in single family homes built after the ordinance. As part of the study, I am currently conducting interviews with people familiar with the ordinance. I am writing to ask if you would be willing to participate in this study and be interviewed. Your experience and insight into residential grey water reuse would be extremely valuable in this project and may assist other municipalities adopting water conserving strategies.

Interviews will be conducted via phone or Skype and will last between a half-hour to an hour. No personal identifiers will be used in the presentation of any information shared or opinions given.

If you have any questions or are interested, please contact me through email (lmb377@cornell.edu) or phone (276-730-5712).

I appreciate your time and I hope to hear from you soon.

Sincerely,
Laura Bell
M.S. Student in Design and Environmental Analysis
College of Human Ecology
Cornell University
276-730-5712
lmb377@cornell.edu

———

Response Email to be sent after participants respond to interview request:

Dear XXX,

Thank you for responding to my interview request, I greatly appreciate the time and insight you are willing to share on residential grey water recycling. Please feel free to contact me with any questions you might have about the study or the interview.

[Confirmation of date/time for interview]

Thank you again for agreeing to participate in this research for a project at Cornell University. I look forward to speaking with you.

Sincerely,
Laura Bell
M.S. Student in Design and Environmental Analysis
College of Human Ecology
Cornell University
276-730-5712
lmb377@cornell.edu

IRB Interview Consent Form

Before we begin, please listen to the following information.

You are invited to take part in a research survey about water conservation in Tucson, Arizona. The following interview will be used in a research project at Cornell University. The purpose of this study is to evaluate to what extent the 2010 Residential Grey Water Ordinance has facilitated grey water reuse, and what the current barriers are to recycling grey water in single family homes built after the ordinance.

During the interview, you will be asked a series of questions about your perceptions of and experience with the 2010 Residential Grey Water Ordinance, as well as other relevant factors related to residential grey water recycling.

The interview will be audio recorded and transcribed to ensure the clarity and accuracy of your statements, however, your identity will remain confidential. Your name will not be used on the audio recording and your name will not be associated in writing with statements you make. Recording the interview will allow the researcher to more accurately represent your viewpoints and beliefs regarding residential grey water reuse. If you do not agree to be taped, the interview may be held the clarity of your viewpoints may not be as well remembered. After the interview, identifying information will be destroyed to protect your privacy and audio recordings will be destroyed after transcription. Interviews last between a half-hour and an hour.

The researcher does not anticipate any risks to you participating in this study.

Your participation in this study is entirely voluntary. You may leave whenever you want or skip any questions you prefer not to answer. Please feel free to ask questions about the study now and after the interview. If you have any concerns or questions after the interview, please email or call the researcher (Laura Bell, lmb377@cornell.edu, 276-730-5712). You may also contact the Institutional Review Board for Human Participants (IRB) with concerns or complaints you might have (irbhp@cornell.edu, 607-255-5138) or make a complaint anonymously through Ethicspoint (www.hotline.cornell.edu or 1866-293-3077).

Thank you for your your help in furthering research on the role of grey water recycling in water conservation. You will be given a copy of this statement for your records.

I consent to be interviewed:

Verbal Consent___________ Date: _____

I am willing to have this interview audio recorded:
Verbal Consent: ________________________ Date:________

This form will be kept by the researcher for at least three years beyond the end of the study and was approved by the IRB on ____________________.

IRB Survey Consent Form

You are invited to take part in a research survey about water conservation in Tucson, Arizona. Your participation will require approximately 20 minutes. There are no known risks or discomforts associated with this survey. After completing the survey, you will be eligible to submit your email address for a raffle to win ________.

Taking part in this study is completely voluntary. If you choose to be in the study you can withdraw at any time without adversely affecting your relationship with anyone at Cornell University. Your responses will be kept strictly confidential, and digital data will be stored in secure computer files after it is entered. Any report of this research that is made available to the public will not include any individual information by which you could be identified.

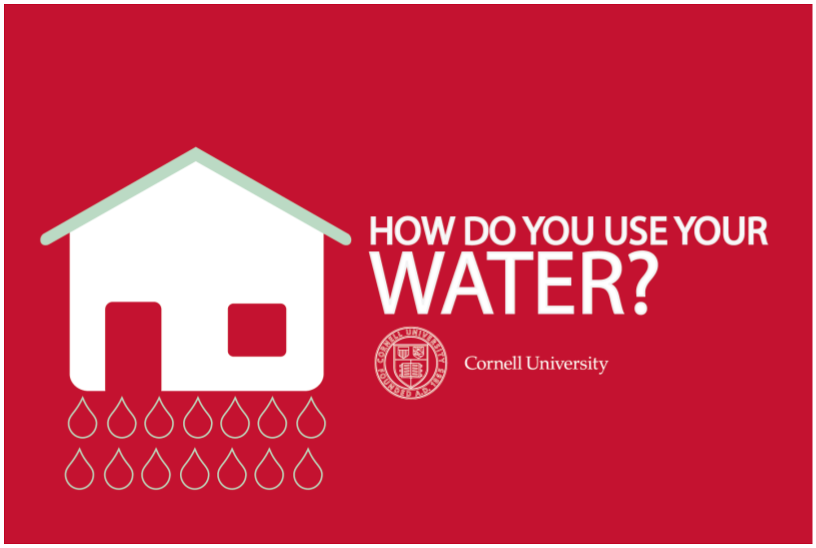
If you have any concerns or questions after the survey, please email the researcher (Laura Bell, lmb377@cornell.edu). You may also contact the Institutional Review Board for Human Participants (IRB) with concerns or complaints you might have (irbhp@cornell.edu, 607-255-5138) or make a complaint anonymously through Ethicspoint (www.hotline.cornell.edu or 1866-293-3077). Completing this survey indicates that you are 18 years of age or older and indicates your consent to participate in the research.

Thank you for your help in furthering research on the role of grey water recycling in water conservation.

[Paper survey: Check box to indicate consent]

[Online survey: Clicking “Continue” indicates consent.]

Invitation Postcards



Website Landing Page

Take Survey Here

TAKE SURVEY   ABOUT

ABOUT

MARCH 06, 2017

Thank you for helping with a master's student research project at Cornell University.

- **The survey should only take 10 minutes, and you will have the opportunity to enter an email address to win a $200 VISA gift card.**
- **If you would like to share your personal experience with water reuse, please contact the researcher here.**

APPENDIX II

SURVEY AND INTERVIEW MATERIALS

Semi-Structured Interview Guideline

Date:____
Interviewee Preferred Title:_____________
Identification number: _____________

1. Are you familiar with the 2010 Residential Gray Water Ordinance passed in Tucson, AZ?
2. What is your understanding of the policy?
    a. What was your role (if any) in the creation of the ordinance?
3. How did different people you know respond to the ordinance? / Did you see differing responses from different industries?
4. Can you think of any problems that plumbers, architects and builders might face in pre-plumbing a house for graywater separation?
5. What do you think the major barriers to using waste water are fort people whose homes have been plumbed for graywater/blackwater separation?
6. To your knowledge, how was the ordinance presented to new single family residence homeowners after the ordinance was passed?
7. Do you think that new homeowners whose homes were built after the ordinance are aware that their houses are plumbed to make recycling graywater easier?
8. It seems to me that it would be easiest to set up a graywater / rainwater reuse system when you are first moving into a home or when you are doing significant renovations. In your opinion, is there an 'easiest' intervention period? If so when?
9. What interventions do you think would be most useful at this point in time for encouraging residential water conservation?
10. Where are the gaps between legislation and on the ground action when it comes to graywater enabling policies like the residential gw ordinance?
11. What would you have changed to make the ordinance / recycling graywater more successful?
12. In a future study, I plan on reaching out to some owners of single family homes built after the ordinance to understand their perspectives. What information would you want to ask homeowners to better understand why they do or do not install gray water irrigation systems?
13. What information would you consider most useful for exploring the success or failure of this ordinance?
14. Do you think an ordinance like this would be successful elsewhere? Do you know of any?
15. Is there anyone else you think I should contact?

Coded Survey

(Introduction Questions)

Welcome

Thank you for participating in a research study on water reuse in Tucson, Arizona! This survey is for a master's degree research project at Cornell University. The purpose of the study is to better understand household water reuse. The survey will only take 10-15 minutes.

After you complete the survey, you have the option to enter your email for a chance to win a $200 Visa gift card (this step is not required). Email addresses will be kept confidential and will only be used to draw a winner.

Your help with this study is greatly appreciated. Your participation is voluntary and you can withdraw at any time. By continuing the survey below, you are agreeing to participate in this study, thank you for your time.

1. Please enter the survey code listed on your postcard: ________

2. Which of the following best describes the landscaping around your home?

- Xeriscape (native plants and rock designs)
- No landscaping
- Some turf grass (green lawn) Other

3. Prior to receiving this survey you heard of graywater before?
(Graywater is the used water from bathroom sinks, showers, bathtubs, and washing machines. It is often possible to reuse this water for landscaping and other purposes)

- Yes
- No

4. Did you know that it IS legal to reuse graywater from your home (if you follow the best practices defined by the state of Arizona)?

- Yes

- No

5. Have you ever heard of Tucson's Residential Graywater Ordinance?

- Yes
- No

When a house is designed to make reusing water easier, builders often place a pipe outlet (called a "stub-out") on the outside of the home. This plumbing pipe can be connected to a source of graywater, like your washing machine.

6. Prior to this survey had you heard about stub-outs before?

- Yes
- No

7. Does your home have a stub-out pipe on the outside of the house?

- Yes
- No
- Not Sure

8. How interested are you in reusing water from your home?

1. Extremely interested
2. Very interested
3. Moderately interested
4. Slightly interested
5. Not at all interested

9. Do you reuse graywater from your home
   - Yes
   - No
   - Yes, in the past but not now because:

10. Please mark ALL of the reasons you have NOT reused graywater from your home

- Not familiar with graywater
- Too expensive to install
- Not sure how to install graywater system
- No need to irrigate landscape

- Too much trouble
- Do not own my home
- Resistance from neighbors
- Would rather participate in the city water recycling program
- Not interested
- Other

(Graywater Users Block)

21. What sources of graywater do you use? (Select ALL that apply)

- Washing machine
- Bathtub or shower
- Hand sinks
- Kitchen sink
- Other

22. How would you describe your graywater system?

- Hand collection: Using buckets or containers to save graywater temporarily
- Plumbing: Graywater collected through piping installed in my house
- Laundry to Landscape: Washing machine connection to irrigation system or pump
- Other

23. Did/do you store your graywater temporarily before using it?

- Yes
- No
- Other ______

24. Did/do you use a pump to distribute your graywater?

- Yes
- No
- Other ______

25. Where was/is your graywater being used? (Select ALL that apply)

- Shade/ornamental trees
- Fruit/nut trees
- Wildflowers/perennials
- Shrub/rose bushes
- Potted plants
- Vegetable/herb garden
- Compost
- Toilet flushing
- Car Washing
- Other

26. How often do you use graywater in the summer?

- Almost every day
- Once a week
- Once a month Hardly ever

27. How often do you use graywater in the winter?

- Almost every day
- Once a week
- Once a month Hardly ever

28. Mark the answer that best describes your feelings about your graywater system.

Strongly agree
Somewhat agree
Neither agree nor disagree
Somewhat disagree
Strongly disagree

- My graywater system works well
- My graywater system is easy to maintain
- It is inconvenient to switch between my graywater system and the sewer
- There are too many inconvenient personal care product restrictions for graywater
- It is easy to find someone to fix my graywater system if it is broken

29. Which of the following would make using graywater easier?

- A maintenance services
- Financial help for installing a graywater system   Help installing the system
- Help with landscaping
- Help selecting plants that can tolerate graywater
- Help with selecting personal care products that will not hurt plants To see an example of how a graywater system works
- Other

(Measures Likert Questions)

11. Please select how much you agree or disagree with the following statements.

Strongly agree
Agree
Somewhat agree
Neither agree nor disagree
Somewhat disagree
Disagree
Strongly disagree

- Most people who are important to me care about water conservation
- Most people who are important to me try to conserve water resources
- Most of my friends and peers engage in water conserving behaviors.

12. Please select how much you agree or disagree with the following statements.

- I think that I myself can contribute to the improvement of water conservation in my city
- I know there are a number of things that I myself can do in order to conserve water
- I believe that together we can do something about water conservation
- I am confident in that we together can solve the water conservation problem in my city

(Demographics)

13. What is your age group?

- 19 or under
- 20-24
- 24-34
- 35-44

- 45-54
- 55+

14. Do you currently own or rent your home?

- I own my home
- I rent my home

15. How long have you lived in Tucson, AZ?

- Less than 5 years
- 5-10 years
- 11-15 years
- 16+ years

16. What is the average income of your household?

- $ 0.00 - $14,999
- $15,000 - $24,999
- $25,000 - $34,999
- $35,000 - $49,999
- $50,000 - $74,999
- $75,000 - $99,999
- $100,000 +

17. What is your educational background?

- Some high school
- High school graduate, diploma or the equivalent (for example: GED)
- Some college credit
- Bachelor's degree
- Master's, Professional or Doctorate degree

18. What is your gender?

- Male
- Female
- Other/NR
-

19. How many adults currently live in your household?

(This question helps explain how much water your household might use)

- 1 Adult
- 2 Adults
- 3 or more adults

20. How many children below the age of 10 currently live in your household? (This question helps explain how much water your household might use)

- None
- 1 Adult
- 2 Adults
- 3 or more adults

Thank you for your participation in this survey!
If you would like to enter to win a $200 visa gift card, please enter an email address below.
A winner will be contacted by May, 2017.

Questions? Email: LMB377@Cornell.edu

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